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Region 9
Superfund Division
San Francisco, CA 94105

September 1997

Response to Comments Water Management Feasibility Study and Addendum

Volume 2 of 5

IRON MOUNTAIN MINE

RESPONSE TO COMMENTS ON THE WATER MANAGEMENT FEASIBILITY STUDY AND ADDENDUM

Volume 2 of 5

IRON MOUNTAIN MINE REDDING, CALIFORNIA

EPA CONTRACT NO. 68-W9-0031
WORK ASSIGNMENT NO. 31-76-9K17
CH2M HILL PROJECT NO. 137295.02.05

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September 30, 1997

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9/25/97	SMC on behalf of R-P	Comments on efficiency of SCDD operations (Response Document: *Letter re Analysis of SCDD Operational Efficiency* and enclosed Responses to *Memorandum re Analysis of SCDD Operation Efficiency for Use in the Iron Mountain Mine Water Quality Model)*	2-682 to 2-707
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6/28/96	Shepherd Miller, Inc., for SMC on behalf of R-P	*Determination of Natural Background Metals Concentrations in Boulder and Slickrock Creeks, Iron Mountain Area, Shasta County, California* (reviewed by Dick Glanzman and John Spitzley of CH2M HILL)	2-755 to 2-782
9/14/95	Shepherd Miller, Inc., for SMC on behalf of R-P	*Preliminary Determination of Background Copper Concentrations in Boulder and Slickrock Creeks, Iron Mountain Area, Shasta County, California*	2-783 to 2-784
6/28/96	Shepherd Miller, Inc., for SMC on behalf of R-P	Comments on naturally occurring substances (Response Document: *Evaluation of the SMI Methodology for Estimating "Natural Copper and Zinc Concentrations" Applied to the Catfish Pond Area, Iron Mountain Mine*)	2-785 to 2-800

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12/26/96	Shepherd Miller, Inc., for SMC on behalf of R-P	Comments on naturally occurring substances (Response Document: *Letter re Response to Comments on Water Management Feasibility Study Addendum for IMM Superfund Site.* Includes section titled *Response to Determination of Natural Background Metals Concentrations in Boulder and Slickrock Creeks, Iron Mountain Area, Shasta County, California. Prepared by Shepherd Miller Inc.*, by Don Mandel/DTSC)	2-887 to 2-899
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9/30/97	SMC on behalf of R-P	*Comments on naturally occurring substances* (Response Document: *Response to Technical Memorandum re Iron Mountain Mine Avian Surveys)*	2-1026 to 2-1027
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3/13/97	Shepherd Miller, Inc., for SMC on behalf of R-P	*Response to Declaration of Rick Sugarek in Support of Plaintiff and Counterclaim Defendant United States of America's Opposition to Defendant Rhone-Poulenc, Inc.'s Motion with Respect to Allegedly "Naturally Occurring" Substances delivered March 13, 1997* (Response Document: *Review of Appendix O to Rhone-Poulenc, Inc.'s Reply Memorandum re Natural Background Levels)*	2-1047 to 2-1070
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4/23/97	Shepherd Miller, Inc., for SMC on behalf of R-P	*Responses to Dr. D. Kirk Nordstrom and Dr. Charles N. Alpers Comments: Attachment 1 to Declaration of Rick Sugarek, dated March 13, 1997* (Response Document: *Review of Appendix Q to Rhone-Poulenc, Inc.'s Reply Memorandum re Natural Background Levels)*	2-1089 to 2-1111
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9/30/97	S. R. Hansen & Associates for SMC on behalf of R-P	*Response to Affidavit of Rick Sugarek (March 13, 1997) Filed in Opposition of Rhone-Poulenc, Inc.'s Motion with Respect to "Naturally Occurring" Substances* (Response Document: *Review of Appendix S to Rhone-Poulenc, Inc.'s Reply Memorandum re Natural Background Levels)*	2-1117 to 2-1126
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2/14/96	S. R. Hansen & Associates for SMC on behalf of R-P	*Letter re Response to Comments Made by CDF&G to (1) Results of SRH&A's January 1995 Ambient Toxicity Testing, (2) Critique of Finlayson & Wilson 1989, (3) SRH&A's Critique of CDF&G's Keswick Sediment Study, and (4) Results of SRH&A's SCDD Effluent Toxicity Testing*	2-1135 to 2-1148
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11/17/94	Ropes & Gray and SMC on behalf of R-P for SMC on behalf of R-P	*Comments Submitted by Stauffer Management Company on Behalf of Rhone-Poulenc, Inc. in Response to October 5, 1994, Request for Written Comments with Respect to a Proposed New Edition and Triennial Review of the Water Quality Control Plan for the Sacramento River (5A) Basin (Basin Plan)*	2-1177 to 2-1178
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7/10/96	Roger K. Patterson/ U.S. Bureau of Reclamation (USBR)	Letter providing USBR comments on Water Management Feasibility Study Addendum	2-35 to 2-51
7/3/96	Dick Forester and Paul Meyer/BLM California State Office	Memorandum with BLM comments on EPA's May 1996 Water Management Feasibility Study Addendum	2-52 to 2-55
5/23/95	Robert L. Shanks/ Sacramento Department of Public Works	Letter providing Sacramento County's response to Proposed Plan for Collection and treatment of Contaminated Slickrock Creek Flows	2-56 to 2-58
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8/15/97	SMC on behalf of R-P	*Response to SMC's Proposed Remedial Alternative for Slickrock Creek Area Point Source Control*	2-181 to 2-209
6/30/96	S. R. Hansen & Associates for SMC on behalf of R-P	Letter with Comments on Public Comment Feasibility Study Addendum	2-210 to 2-214
8/94	SMC on behalf of R-P	Proposal to treat contaminated Slickrock Creek baseflows as a "stand alone" remedial alternative	2-215 to 2-232
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7/1/96	Spaulding Environmental Associates, Inc., for SMC on behalf of R-P	*Evaluation of Revised Iron Mountain Mine Water Quality Model and its Application to Slickrock Creek Remediation*	2-318 to 2-352
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9/30/95	Morrison Knudsen Corporation for SMC on behalf of R-P	*Iron Mountain Mine Off-Site Metals Loading during 1995 Storms*	2-353 to 2-510

Review of Memorandum re Comments on Appendix E–Laboratory Precipitation Studies, Field Precipitation Studies, Filter Studies

PREPARED FOR: Rick Sugarek, U.S. EPA

PREPARED BY: Ray Prettyman/CH2M HILL

Description of Document

This document, a memorandum *re Comments on Appendix E–Laboratory Precipitation Studies, Field Precipitation Studies, Filter Studies* (Paul Ekoniak, June 9, 1996 [SMC Vol. 63, Tab 4]), presents the author's comments on Appendix E of U.S. Environmental Protection Agency's (EPA) *Public Comment Water Management Feasibility Study Addendum* (May 1996). The document only addresses the filter contamination studies conducted by Basic Laboratory and EPA, and includes the following attachments as support to the author's contention that the January 1995 offsite samples were contaminated:

- May 17, 1995, correspondence from Paul Ekoniak to Mary MaloneyHuss regarding *Iron Mountain Sampling Quality Assurance Review Data Quality.*
- June 21, 1995, memorandum from Jim Hawley/Basic Laboratory to Paul Ekoniak regarding *Filter Contamination During the January Storm Event.*
- April 4, 1995, memorandum from D. Graham to M. MaloneyHuss concerning *Data Quality: Iron Mountain Water Samples Collected January through March 1995.*
- April 10, 1995, memorandum from John List/Flow Science to Joseph Kelly and Mary MaloneyHuss regarding *Accuracy of Analysis of Iron Mountain Samples for Total and Dissolved Cu, Cd, and Zn Concentrations.*
- April 4, 1995, memorandum from Tom Pangburn to Paul Ekoniak regarding *Data Quality: Iron Mountain Water Samples Collected February through March 1995.*

The last three memoranda listed above as attachments to the Ekoniak June 9, 1996, memorandum were also attached to another memorandum which was reviewed elsewhere in these responses to comments. See the technical memorandum reviewing the Memorandum re *Iron Mountain Sampling Quality Assurance Review Data Quality*, Paul Ekoniak/Zeneca Inc., dated May 17, 1995.

Major Comments in Document and Responses

Major findings in this document and our responses are presented below.

Comment: The Whatman filter batch differences may have impacted the results of EPA's filter experiment.

Response: The manufacturer of the Whatman filters was contacted regarding filter batch differences. The manufacturer stated that it would not expect much variation, if any, in the filters because of different lot numbers and that it was the nature of the filter (a glass fiber backing under the 0.45-micron membrane) that would cause metals leaching or adsorption depending on the conditions. The implication is that the manufacturing process was such that the variation from lot to lot would be minimal.

Comment: Sacramento River chemistry differences between the time of Basic Laboratory's tests and EPA's tests could have impacted results.

Response: According to the information provided in Jim Hawley's memorandum dated June 21, 1995, Basic Laboratory's filter study was not conducted using Sacramento River water. The study was conducted using deionized water, acidified deionized water, and City of Redding tap water. Therefore, Basic Laboratory did not obtain Sacramento River water for comparison to the EPA Sacramento results.

Comment: The tap water used by the EPA laboratory comes from Whiskeytown Lake, whereas the City tap water tested by Basic Laboratory comes from the Sacramento River. It is unknown whether this difference has impacted the results.

Response: The tap waters used by Basic Laboratory and the EPA lab are both supplied by the City of Redding. As stated by Stauffer Management Company (SMC), they originate from different sources and are treated by two separate City water treatment plants. The memorandum from Basic Laboratory dated June 21, 1995, provides only one piece of filtration study data using tap water with the Whatman filter. Therefore, it is not possible to determine if the resulting copper and zinc increases were caused by the pickup of these metals from the filter or if they came from another source. The filter study conducted by the EPA laboratory consisted of seven replicate analyses so the resulting data could be statistically evaluated.

Because the tap waters had undergone treatment and chemical additions, they were not chemically the same as the original water sources. Therefore, even if the tap water used by Basic Laboratory had caused a pickup of metals from the filter, it cannot be assumed that untreated Sacramento River would also pick up metals.

Comment: Basic Laboratory properly identified and quantified the filter contamination from the use of Whatman filters during the January 1995 storm event.

Response: The data provided in the Basic Laboratory memorandum dated June 21, 1995, does not provide sufficient information for us to evaluate its results. To determine if the samples obtained from the Sacramento River caused a pickup of metals, then Sacramento River water should have been used in the study as was employed by the EPA laboratory. Also, replicate samples should have been filtered and analyzed to determine the statistical significance of the results.

Comment: Basic Laboratory testing was conducted closer in time to the storm event, used the same filters as were used for the preparation, and the tap water samples and Sacramento River samples did result in contamination.

Response: There is no real significance that the Basic Laboratory testing was conducted close in time to the storm event. Basic Laboratory probably did not use the same filters; they probably used filters from the same lot number as the ones they used to filter the samples. As mentioned above, if the single result with tap water was correct, the treated tap water was not representative of the water in the Sacramento River. No filtration study data were provided that used Sacramento River water to determine its ability to pick up metals from the filters.

Comment: During the January storms, analytical results obtained from samples collected by other agencies were lower than the Basic Laboratory reported results.

Response: During January 1995, samples were collected below Keswick Dam by the Regional Water Quality Control Board, California Department of Fish and Game, U.S. Bureau of Reclamation, Central Valley Project, and SMC. Comparing SMC's copper and zinc results for their samples with the results from the various agencies, SMC's dissolved zinc results from January 15 through January 19 were significantly higher than the agencies' results. However, the copper results do not appear to be outside the range obtained by other agencies.

Comment: SMC found that another source of possible contamination during the January storms was random contamination resulting from the sampling container.

Response: No data have been made available to EPA to support this contention. SMC's *Assessment of Water Quality Parameters at the Iron Mountain Mines Redding, California*, dated December 1, 1994, states that field blanks will be submitted for analysis with each set of data for the M-W-F samples. One purpose of field blanks is to determine if the sample bottles have become contaminated. If field blank data were obtained, the results were not made available to EPA.

Comment: Nothing in the EPA experiment refutes the findings of Basic Laboratory and SMC.

Response: The EPA filter study found that the performance of the test filters was unacceptable for dissolved zinc analyses. However, the test filters performed acceptably for dissolved copper analyses in either the Sacramento River water samples or in tap water samples.

Comment: Since the testing conducted by Basic Laboratory was done with the original filters and river samples, the Basic Laboratory testing provides a more realistic evaluation of the problem.

Response: As described above, according to the information provided by Basic Laboratory, that lab did not use Sacramento River water in its filter study.

Review of Memorandum re Feasibility Study Addendum and Water Quality Model

PREPARED FOR: Rick Sugarek/U.S. EPA

PREPARED BY: Ray Prettyman/CH2M HILL

Description of Document

This document is a memorandum dated June 18, 1996 [SMC Vol. 63, Tab 5], from John List/Flow Science Incorporated to Mary MaloneyHuss and Joseph Kelly/Stauffer Management Company (SMC) *re Public Comment Water Management Feasibility Study Addendum* [FSA] *Volume I and II and IMM Water Quality Model Version 2 Documentation*. Flow Science's memorandum includes the following attachments:

- Report from J. J. Morgan, dated June 6, 1996, and June 18,1996, titled *Comments on the Laboratory Precipitation and Field Precipitation Studies QAL Document*. This report presents Morgan's interpretation of Quality Analytical Laboratory's (QAL) laboratory and field precipitation studies.

- An article by A. J. Horowitz, et al., titled *Problems Associated with Using Filtration to Define Dissolved Trace Element Concentrations in Natural Water Samples*, Environmental Science and Technology, 1996, 30, 954-963. This article presents the results of a study comparing different filter properties with dissolved metals concentrations.

- A memorandum from John List/Flow Science Incorporated, dated April 10, 1995, to Joseph Kelly and Mary MaloneyHuss/SMC *re Accuracy of Analysis of Iron Mountain Samples for Total and Dissolved Cu, Cd, and Zn Concentrations*. The memorandum presents total and dissolved copper, cadmium, and zinc results for various samples analyzed by Flow Science.

Major Findings or Major Review Comments in Document and Responses

Comment: A major criticism of the prior U.S. Environmental Protection Agency (EPA) work was that historical data used to support the modeling work were almost certainly flawed. It was shown that on all recorded occasions for which dissolved copper concentrations in the Sacramento River had equaled or exceeded 13 parts per billion (ppb), the complete data actually revealed that the measured total concentration of copper was less than or equal to the dissolved concentration, thus placing the validity of the data seriously in doubt.

> **Response:** As pointed out in the technical memorandum responding to Flow Science's August 17, 1994, *Review and Analysis Proposed Iron Mountain Mine Remediation Study*, the data which Flow Science refers to are not flawed and are considered valid.

Comment: The fact is, the fraction of copper entering Keswick that passes out of Keswick Reservoir is determined by the mass of copper that sediments to the bottom of Keswick, and this is controlled almost completely by the hydrodynamics of the mixing process and by the rate of particle coagulation and sedimentation in the Reservoir. These processes, which are fundamental to the mass balance of copper and other metals in the reservoir, were simply ignored in the EPA laboratory work and incorrectly represented in the modeling.

Response: It is agreed that one of the elements that determines the mass of total metals leaving Keswick Reservoir is the settling of particulate solids in the reservoir. However, the Water Quality Model (WQM) deals with dissolved metals, not total metals that include the particulate fraction. Thus, the laboratory study separated the particulate solids from the dissolved fraction using filtration. The study was not attempting to simulate particulate removal by sedimentation.

Comment: The basic fallacy in the EPA tests and modeling is to assume that all of the copper is available to come to equilibrium with all of the water in the reservoir. However, it is an indisputable fact, documented by the U.S. Geological Survey (USGS), that much of the copper entering the reservoir falls to the bottom in the Spring Creek arm of Keswick Reservoir and is not available to come to equilibrium with the river water in the main stream.

Response: Bottom sediments in the Spring Creek arm and within Keswick Reservoir have been identified and mapped. However, it is not true that most of the copper entering the reservoir settles to the bottom in the Spring Creek arm. During February 8 and 9, 1996, extensive sampling was performed in Keswick Reservoir, including the Spring Creek arm. A mass balance performed using these data indicated that less than 10 percent of the copper entering the Spring Creek arm was removed. Data collected around Keswick indicate that under low-flow conditions, some settling may occur. However, under high-flow conditions, these bottom sediments are resuspended and move into the Sacramento River.

Comment: Which analysis of the preceding two is correct (referring to a comparison of copper removal in Keswick–EPA vs. Flow Science methodologies)? Certainly not the EPA model, because that analysis presumes that all of the copper is available to equilibrate with all of the river water. We know from the USGS field work in the Spring Creek arm and the river bed sediments that this is definitely not the case. The simplified example of a staged dilution offered above is probably not totally correct either because, as will be demonstrated later, the EPA laboratory analysis has almost certainly overestimated the fraction of copper that remains dissolved when the total copper concentration is high. Thus, the simplistic estimate made above is almost certainly a far more plausible estimate of the fraction of dissolved copper leaving Keswick than the computation made using the EPA model.

Response: The actual removal of copper in Keswick Reservoir, as demonstrated by mass balances, confirms that EPA's model closely approximates what is occurring in the reservoir.

Comment: Furthermore, if the suspension is destabilized, such as occurs when the acid mine drainage (AMD) is mixed with river water, the fraction of particles passing a 0.45-micron filter can be reduced from 75 percent to 25 percent after two hours of aging. It should be noted that these studies were performed with iron as the tracer material and sea water as the destabilizer, but it is known the copper adsorbs strongly to iron particles, and insoluble copper-containing particles formed by mixing AMD with river water will behave in an exactly analogous way because the mechanisms are identical.

Response: The composition of sea water is so different from the composition of the waters in Keswick Reservoir that this comment is not relevant.

Comment: The key point here is that the particle size distribution in a reservoir does have an opportunity to age, and the effect of the aging process is to move the average particle size to larger sizes which sediment faster. Thus, the fraction of particles in the size distribution that will pass through a 0.45-micron filter will be reduced as the diluted mixture ages. The laboratory tests were therefore biased significantly in favor of maximizing the "dissolved" fraction.

Response: The actual effect of the aging process on reducing the fraction of particles that will pass a 0.45-micron filter was determined during the February 8 and 9, 1996, monitoring within Keswick Reservoir. According to these monitoring data, there was no significant difference in the dissolved-to-total copper ratio in the samples KRSC6 through KRSC3 as the waters traveled through the Spring Creek arm and into Keswick Reservoir. Also, as mentioned above, the removal of total copper through this reach of Keswick was less than 10 percent. The laboratory data closely approximated what was actually measured in Keswick Reservoir.

Comment: The second important failing of the laboratory tests was that no opportunity for sedimentation was permitted. The tests with insoluble copper, iron, and aluminum precipitates present did not allow these to settle from solution. The beakers were continuously stirred, thereby preventing any sedimentation. In the Spring Creek arm of Keswick Reservoir the dilution is initially low, so there is the opportunity to form insoluble copper compounds which can coagulate and can also be captured by other flocculent precipitates that form. This copper, together with adsorbed copper, is removed from solution by sedimentation, falling to the bottom in the Spring Creek arm of the reservoir, where it can play no part in the equilibrium chemistry of subsequent dilution. Thus, in the reservoir, when the mixture reaches an ultimate dilution, there is significantly less total copper present than there would be if a very high dilution immediately occurred.

Response: Data collected during February 8 and 9, 1996, showed that greater than 90 percent of the copper, iron, and aluminum entering the Spring Creek arm moved on into the main body of the reservoir. Therefore, the hypothesis that there is significant removal of copper in the Spring Creek arm does not match the actual field measurements.

Comment: Since no aging or sedimentation was permitted in the laboratory tests, they grossly overestimated the fraction of copper appearing to be dissolved. This is confirmed by the data in Table E-4, which show that for six measurements taken in the Sacramento River downstream of Keswick Dam on December 12, 1995, the day of a major storm event in the area, the average concentration of "dissolved" copper was about 25 percent of the total copper, despite the fact that the average total concentration of copper in six samples across the river was measured at 22.2 ppb. If the EPA laboratory data were truly representative of what was occurring in the river, then the "dissolved" concentration should have been about 16.7 ppb, whereas it was actually measured at an average of 5.5 ppb.

Response: The sampling point (SRK18) referred to in this comment is located in the Sacramento River downstream of Keswick Reservoir. From a comparison of total and dissolved copper data between SRK18 and the compliance point immediately below Keswick Reservoir, it appears that sediments within the Sacramento River were disrupted by storm water flows and carried downstream to SRK18.

Comment: The data from the vicinity of the Spring Creek arm with higher copper levels (KRSC4A-B, Table E-5) have total copper concentrations of about 27 micrograms per liter (µg/L) with about 60 percent in the "soluble" [*sic*] category at about 17 µg/L. This should be compared to the total copper levels at KRSC3A-B, which is located slightly further down the reservoir, where the total copper levels were about 8 µg/L, and the dissolved copper levels at about 5 µg/L. The data in Table E-5 therefore indicate quite clearly that, during the period of data collection, there was a significant deposition of copper within the Spring Creek arm and that the aging of the AMD/River mixture led to a loss of both "dissolved" and "total" copper, while at the same time there was an increase in the fraction of "dissolved" copper. This is precisely what would be expected on the basis of the physical chemistry of the mixtures, and the results simply have nothing to do with the EPA model which assumes a 30 percent precipitation.

Response: As shown in Figure 2-27 in Volume I of EPA's May 1996 FSA, Sampling Site KRSC4 is located in the Spring Creek arm of Keswick Reservoir and represents the combined flows and metal loadings from Spring Creek Debris Dam (SCDD) and the Spring Creek Powerhouse. Sampling Site KRSC3 is located in the main body of Keswick Reservoir and represents the combination of the water from the Spring Creek arm diluted with the water from Shasta Dam. A simple mass balance shows that the lower concentration of copper measured at KRSC3 as compared to KRSC4 is due only to dilution, not the deposition of copper.

Comment: The fact is that EPA did find contamination of filtered zinc samples and contamination of acidic copper samples. Given the documented experience of other independent scientists, the fact that it did find copper contamination of non-acidic samples cannot be used as a basis for either (a) the conclusion that SMC's measurements in January of 1995 were not contaminated, or (b) the conclusion that SMC's data can therefore be used to verify a (flawed) computer model.

Response: As explained in the FSA, according to the results of the filter tests performed by both SMC's laboratory and EPA's laboratory, the unacidified dissolved zinc analyses were found to be contaminated, and the SMC January dissolved zinc data not usable. However, the dissolved copper data for unacidified Sacramento River water and City of Redding water did not show contamination by the filter, and therefore the SMC data were considered usable.

Contamination during filtration appears to be filter-specific. The filters used by SMC's laboratory were reported to be Whatman Autovial 0.45-micron PVDF membrane filters. These were the same filters evaluated by EPA's laboratory. Flow Science's attachment to its report indicated that Gelman 0.45-micron PTFE (Teflon) syringe filters were used for their laboratory filtration studies. The second attachment to the Flow Science report (Horowitz, et al.) stated that three different filters were evaluated: (1) a 47-millimeter (mm), 0.40-micron polycarbonate Nuclepore plate filter, (2) a 142-mm, 0.45-micron cellulose nitrate MicroFiltration Systems plate filter, and (3) a 47-mm, 0.45-micron polyethersulfone Gelman capsule filter. No documented experience by independent scientists using the Whatman Autovial 0.45-micron PVDF membrane filter has been presented to EPA.

Comment: Feasibility Study Addendum (FSA), Volume I, page 1-3, regarding "The EPA has determined that this alternative would not meet remedial action alternatives." -- These remedial action alternatives do not appear to be clearly stated anywhere.

Response: As stated in Section 4.1.1 of EPA's June 1994 *Public Comment Water Management Feasibility Study*, the overall remedial action objective at the site is to eliminate acid mine drainage (AMD) discharges that are harmful to public health and the environment. Currently, available information indicates that this goal could be met by eliminating site discharges that result in the exceedance of the State Basin Plan standards.

Comment: FSA, Volume I, page 1-7, regarding "The impacts on the Sacramento River fishery were significantly reduced through treatment..." -- Where is the evidence for this?

Response: The projected reduction of impacts on the Sacramento River fishery was the reduction of uncontrolled spill events and the metal concentrations from the SCDD. Over the past three years, more than 80 percent of the copper and zinc loads generated at the site have been collected and treated at the IMM treatment plant.

Comment: FSA, Volume I, page 2-2, regarding "The flows in the Sacramento River available at the onset of major storm events cannot generally provide adequate dilution..." -- Where is the evidence for this?

Response: As explained in Section 2.1.1 of the FSA, EPA has calculated the Sacramento River flow required to ensure the dilution of Iron Mountain Mine (IMM)-contaminated Spring Creek Reservoir waters to meet water quality objectives. According to the historical flow data, during the first storm of the season, the Sacramento River flows that can generally be expected could not provide adequate dilution at current levels of contamination.

Comment: FSA, Volume I, page 2-8, regarding "California Department of Fish and Game (CDFG) studies have shown that the toxic constituents of these sediments can be resolubilized if the sediments become resuspended, such as under turbulent conditions." -- Our reading of the CDFG study showed that if the sediments were centrifuged at 1,000s of g's, then toxic water was released from the sediments. They did not show that this would occur if the sediments were simply mixed with the river water. In fact, there are strong chemical reasons to believe that if the sediments were mixed through the water column, they would remove more metals from the river water.

Response: The CDFG report, dated March 31, 1995, stated that the elutriate water toxicity test they employed simulates the conditions that occur during an actual discharge of sediments in the Sacramento River. There is no evidence, of which we are aware, that supports the idea that resuspending the sediments in Keswick Reservoir would lead to removal of more metals.

Comment: FSA, Volume I, page 2-14, regarding "The results are empirical measurements of the laboratory simulation of conditions like those encountered in Keswick Reservoir..." As shown above, the laboratory studies certainly were very far from a simulation of conditions in Keswick Reservoir.

Response: In the laboratory tests, water from SCDD was blended with waters from Whiskeytown Reservoir and Shasta Dam as occurs in Keswick Reservoir. The close agreement between the laboratory results and actual field measurements indicates that the laboratory simulation was quite good.

Comment: FSA, Volume I, page 2-15, regarding "...these field measurements provided verification of the results of the laboratory experiments." -- As shown above, there is simply no basis for this claim.

Response: EPA believes the field results verify the laboratory results because the dissolved cadmium, copper, and zinc concentrations in the Sacramento River below Keswick Dam closely agree with the predictions from the laboratory tests.

Comment: FSA, Volume I, page 2-15, regarding "In general, the solubility of metals measured throughout the Sacramento River correlate well with the solubility properties developed in the laboratory precipitation experiments and are consistent with the laboratory experiments discussed in Section 2.2.2.1." -- This statement is refuted by the measurements at Station SK18A-J, which are completely at variance with the laboratory solubility properties. In any case, the laboratory tests did not measure "solubility."

Response: The term "solubility," as used in this context, refers to the metals that pass through a 0.45-micron filter. Measurements at Station SRK18A-J during the February 8 and 9, 1996, intensive monitoring period were in close agreement with the laboratory results. On December 12, 1995, the total copper concentration at this sampling site was very high as compared to the dissolved copper concentration. It appears that the high total copper concentration was caused by bottom sediments being scoured during the heavy rainfall event on December 12, 1995.

Comment: FSA, Volume I, page 2-16, regarding "the same study by Finlayson presents evidence that the sediments are toxic to aquatic life and represent a hazard downstream of Keswick Dam." -- This statement mischaracterizes the results obtained by Finlayson, which apply to the water extracted from the sediments by extremely high revolutions per minute (rpm) centrifuging. There is no work, familiar to us, to indicate that the sediments mixed with river water represent a hazard to life downstream of Keswick.

Response: The CDFG report states that the elutriate water toxicity test that was employed simulates the conditions that occur during an actual discharge of sediments in the Sacramento River. The results of this study give evidence that the sediments are toxic to aquatic life. In addition to the toxicity tests conducted with sediment elutriate waters, the toxicity studies conducted by the California Department of Fish and Game included tests with bulk sediments using an infaunal amphipod *(Hyallea azteca)*. The results of these tests indicated that sediments from all of the sites on the Spring Creek arm of Keswick Reservoir showed toxicity to this test organism with mortality with an average mortality of 58 percent and a range of 10 to 100 percent mortality. Furthermore in the 3 sediments tested downstream of the Spring Creek Arm in the main channel of Keswick Reservoir, the mean mortality to the sediments tested was 77 percent and ranged from 35 to 100 percent mortality. Clearly, these results indicate that these metal contaminated sediments as well as the elutriate waters were toxic to the organisms tested in these studies.

Comment: FSA, Volume I, page 2-17, regarding "...2-day, and 3-day events in January will likely occur every 5 to 10 years."

Response: No comment was presented following this quotation from the FSA. Therefore, no response is given.

Comment: FSA, Volume I, page 2-20, regarding "...most methods estimate return periods between 5 and 10 years for the 1-, 2-, and 3-day events. In other words it is likely that..." The first and third of these statements seem a calculated exaggeration given the data in Table 2-5, and the fact that the DWR analysis did not include the years 1987-1995. The data in Table 2-5, more realistically, can be said to have a return period of 10 to 18 years for 1-day events and 9 to 13 years for 2- and 3-day events. The statement is made that the Morrison Knudsen (MK) data contained six drought years. The fact is, this is the actual data record. It is unreasonable to exclude these years in the analysis and quote the results of the Department of Water Resources (DWR) analysis as if they are reasonable. The impression is left that the events that occurred in January of 1995 could be reasonably expected to have a return period of 5 years, which is definitely not the implication of all but one of the analyses.

Response: Table 2-5 in the FSA presents the return periods estimated by DWR, MK, EPA, and Spaulding Environmental Associates (SEA). None of the four estimates were excluded. The rainfall period used as the basis for each of the four estimates is presented as a footnote to the table. Considering 1-, 2-, and 3-day events as a set, a general statement of a return period of 5 to 10 years appears reasonable. It is agreed that just considering a 1-day return event, there would be a greater estimated return period.

Comment: FSA, Volume I, page 2-34, regarding "SMC has extracted copper and zinc data from January 13 to 23 because of an alleged contamination problem." -- The contamination problem is not alleged - it is a proven problem. See the comments above.

Response: As discussed in the FSA, EPA agrees that the filters used by SMC's laboratory did introduce random low-level zinc contamination. However, EPA also found that the extent of potential dissolved copper contamination for neutral pH samples was insignificant.

Comment: FSA, Volume I, page 2-39, regarding "The extent of potential soluble copper contamination for samples collected below Keswick Dam was insignificant, and the data should be used for estimating the performance of SCDD during this time period." -- The fact is, SMC's data in this period were higher than the data collected by five other agencies. The filter contamination problem has been well documented by independent and peer-reviewed scientific analysis. Use of these data to suit EPA's purposes is plain bad science and unconscionable.

Response: As discussed above, EPA knows of no studies that document copper contamination by Whatman Autovail 0.45-micron PVDF membrane filters. Table 2-6 of the FSA presents data collected by SMC and various agencies during January 1995. Comparing SMC's dissolved copper data with that of five agencies and applying an analytical precision of ±20 percent, except for the data collected on January 19, 1995, the range of data collected by the agencies is in agreement with the SMC data.

Comment: Volume I, page 2-40, regarding "This approach assumes that 30 per cent of the copper discharged from SCDD precipitates in the mixing zone of Keswick Reservoir..." -- As pointed out in significant detail elsewhere in this document, there is simply no basis for this assumption. In all likelihood, there is a high probability that as much as 75 percent of the copper passing into Keswick Reservoir remains in an insoluble form.

Response: This assumption is based on mass balances of copper within the Keswick Reservoir which show that the 30 percent is a reasonable estimate.

Comment: FSA, Volume I, page 2-53, regarding "EPA believes that the January 1995 SMC copper data can be relied upon to assist in characterizing..." -- As noted above, the deliberate use of questionable data in the face of overwhelming evidence that the dissolved copper data was almost certainly compromised is unacceptable.

Response: As discussed above, EPA believes SMC's January 1995 dissolved copper data is valid and can be used to assist in characterizing the conditions experienced in the Sacramento River.

Comment: FSA, Volume II, Appendix E, -- The site map does not show the locations of SRK2 or SRK18, nor are these acronyms included in the List of Acronyms.

Response: Sampling Sites SRK2 and SPK18 are shown on Figure 2-27 of the FSA. The locations are described on page E-7 in Appendix E.

Comment: FSA, Volume II, Appendix E, -- Figure E-2 is mislabeled. The title should refer to Experiment No. 2

Response: The comment is correct.

Comment: FSA, Volume II, Appendix E, -- Figure E-3 is mislabeled. The title should refer to Experiment No. 1.

Response: The comment is correct.

Comment: FSA, Volume II, Appendix E, -- Figure E-4 has plotted points that are not in the data tables.

Response: There are several points for dissolved copper that were plotted more than once. However, this chart and those data points are not used for any calculations. The overall trends and visual patterns remain essentially the same.

Comment: FSA, Volume II, Appendix E, -- Figure E-7 has plotted points that do not correspond to the data for Experiment No. 1.

Response: Three values for dissolved copper appear to have been transcribed incorrectly into the table for Experiment 1. The values are off by less than 3 ppb.

Comment: FSA, Volume II, Appendix E, page E-16, regarding "The solubility of copper, cadmium, and zinc at the compliance point (SRK2) agree closely with the predictions from Section E-2 of this appendix, inferring [sic] that the use of those derived solubility functions in the water quality model is valid." -- If the derived solubility functions in the water quality model were valid, they would imply dissolved copper concentrations of 16.6 ppb at SRK18A-J, not the average 5.5 ppb measured at these locations on December 12, 1995. To imply that the validity of the "solubility" model has anything to do with the validity of its use in the water quality model either displays a complete lack of understanding of the reservoir mixing and chemistry, or is disingenuous.

Response: The WQM is used to predict dissolved copper concentrations at SRK2, a sampling point located in the Sacramento River immediately below Keswick Dam. The model relies upon a precipitation function to reflect the processes by which dissolved metals from IMM precipitate out and become a component of the non-dissolved fraction of the total metals as the IMM AMD mixes in Keswick Reservoir with the cleaner waters from Lake Shasta, Whiskeytown Reservoir and other flows (such as accretion flows during and after precipitation events). EPA relied upon laboratory and field investigations to develop this relationship. These studies focused upon the unique characteristics of Keswick Reservoir because that is the area where IMM AMD mixes with the Sacramento River waters.

The FSA section referred to in the comment simply notes that the value predicted by the model is in close agreement with the value actually measured at sampling point SRK2. The close agreement between the modeled number and the actual value indicates that the model is functioning properly.

Rather than focus upon the sampling point that is the focus of the model, the commenter attempts to infer the values that the EPA model would predict at a different location and based upon a different set of assumptions. In particular, the commenter attempts to back calculate the dissolved copper concentration from the total copper concentration at sampling point SRK18A-J. The EPA solubility function is not intended to function in that manner, namely calculating the dissolved fraction based upon the total copper value in the Sacramento River below Keswick Dam. Instead, the EPA model estimates the amount of dissolved metal that will precipitate as a function of the "calculated" total metal concentration of the mixture of the SCDD release and assumed low background concentrations of total metals in the Shasta Lake and SCPH releases. During storm periods (such as the December 12, 1995 period) the measured "total" concentrations in Keswick Reservoir may be significantly greater than the "calculated" total concentrations due to erosion of soils containing total metals. Use of this measured value would significantly distort the model calculation of "dissolved" metals. As discussed above, the EPA model is specific to the unique conditions in Keswick Reservoir, so applying the function in downstream areas would not be expected to a reliable indicator of the appropriateness of the function for Keswick Reservoir.

Using the downstream total metal concentrations in the Sacramento River below Keswick Dam as a proxy for dissolved metals leads to problems under certain circumstances, such during storm periods when disturbance of stream sediments can increase total metals but not necessarily increase dissolved metals. In fact, a storm on December 12, 1995, appears to be the most likely cause of the unusually high total copper concentrations measured at sampling point SRK18-A-J. The unusually high total copper concentrations (relative to the dissolved fraction) at this downstream point indicates that the storm disrupted sediments within the Sacramento River below Keswick Dam. The disturbance of the sediments would explain the increase in total metals.

Comment: FSA, Volume II, Appendix E, page E-16, regarding "Dilution and equilibrium are reached well before Keswick Dam (KRSC2&3 results versus SRK2 results)." In fact, a review of the limited data for the three sites quoted (plus SRK18) for the available days of February 8 and 9, 1996, shows that the average fraction of "dissolved" copper increases from about 64 percent to 78 percent moving from KRSC2 to SRK18. The data are very revealing:

	KRSC3	KRSC2	SRK2	SRK18
2/08/96	65%	100%	70%	77%
2/09/96	63%	70%	74%	78%

The data for KRSC2 on February 8, 1995, have a problem since they actually show more dissolved than total copper. The other data are averages of at least four data points. The trend is clear and it is exactly what would be predicted on the basis of the aging of a mixture with a low overall copper concentration, i.e., a steady shift from a lower fraction of dissolved copper to a higher fraction because the copper in the fraction larger than 0.45 microns is being lost from the water column.

Response: The dissolved copper data for the four sampling locations cited above were:

	KRSC3	KRSC2	SRK2	SRK18
2/08/96	4.8 ppb	5.4 ppb	5.5 ppb	5.3 ppb
2/09/96	5.5 ppb	5.1 ppb	5.6 ppb	5.3 ppb

The data fall within the expected analytical precision of ±20 percent, and do not indicate a significant decrease in dissolved copper concentration. The increase in the percent dissolved copper fraction is primarily from the decrease in the total copper concentration that is probably caused by settling out of particulate solids.

Comment: Regarding the IMM Water Quality Model Version 2 Documentation, the point has been adequately made elsewhere that this model is completely flawed and does not represent what occurs in Keswick Reservoir. As previously stated, the basic fallacy is to assume that all of the copper and zinc are available to reach an equilibrium with all of the dilution water, which the field studies make abundantly clear does not occur. As a consequence, the model grossly overestimates the fraction of copper remaining in the "dissolved" category.

Response: EPA believes that SMC has offered no valid arguments to support their contention that the WQM is flawed and grossly overestimates the fraction of dissolved copper.

Comment: (Attachment from J. J. Morgan) The QAL states (p. E-2) that "...assumptions regarding pH and hardness/alkalinity that were relied on in the Flow Science/Morgan calculations are not conservative." I see no need for "conservative" or non-conservative assumptions about pH and alkalinity.

Response: The comment in the FSA refers to work conduct by Dr. John List on behalf of SMC. Dr. List relied upon several assumptions to conclude that certain metal concentrations would never occur in and below Keswick Reservoir. Dr. List claimed that his assumptions were "conservative" so that the actual maximum values would be even lower than the ones he predicted in his analysis. Data obtained since the time of that analysis indicates that the assumptions underlying the analysis by Dr. List were incorrect. During recent storm events, pH values well below the minimum predicted by Dr. List have been observed. These data show that Dr. List's assumptions were far from conservative.

Comment: (Attachment from J. J. Morgan) Tables E-3 and E-4 report ferrous iron concentrations of 10 mg/L. This would appear to be an error. One does not expect such high concentrations of dissolved, reduced iron in oxygenated waters at elevated pH values. It is also puzzling that so many of the ferrous iron values are identical.

Response: A "less than" sign was inadvertently left out in front of the ferrous iron data in Tables E-3 and E-4.

Comment: (Attachment from J.J. Morgan) The fraction of "dissolved" copper in the various waters for which data are reported in Tables E-3 through E-6 ranges from about 60 percent to 75 percent. The corresponding fraction for lower total copper (TOTCu) in the laboratory experiments is said to be about 78 percent. However, as was recently pointed out to me, more extensive data available on copper fractionation in the rivers show a much smaller fraction of "dissolved" copper, ranging down to about 20 percent and less.

A plausible hypothesis to account for these lower "dissolved" copper concentrations in the field is the following: (I) The field data on the "dissolved" fraction represent copper in true solution, given a long time for adsorption and for coagulation in the water column, e.g., through particle collisions by differential settling; colloidal particles containing copper then have a greater opportunity to coagulate and move into the filtration fraction. (II) The lab data reflect the presence of appreciable concentrations of colloids, (<0.45 micron) particles, which have had little opportunity to coagulate out of the small particle size range. In my opinion, the laboratory experiments reported in the QAL document are inadequate as simulators of the copper fractionation expected under natural conditions.

Response: The laboratory study was designed to simulate dissolved copper removal in Keswick Reservoir, not downstream in the Sacramento River. The fraction of dissolved copper concentration in the Sacramento River below Keswick Reservoir is possibly affected by scouring of sediment deposits in the river bed during high flows. Thus, if these sediments are resuspended, they will show up in the analytical results as total copper; however, the dissolved copper concentration may remain relatively unchanged. Although scouring could cause a decrease in the percentage of the dissolved copper fraction, the dissolved copper concentration may remain essentially the same. This phenomenon is observable in the available data on December 12, 1995. Although the ratio of dissolved to total copper decreases, the dissolved copper concentrations remained relatively constant. This data suggests that scouring increases the total copper values but does not always increase the dissolved copper concentration.

Review of Iron Mountain Mine Off-Site Metals Loading During January 1995 Storm and Anne C. Connell Declaration

PREPARED FOR: Rick Sugarek/ EPA

PREPARED BY: John Spitzley/ CH2M HILL

This memorandum provides an evaluation of two analyses submitted by Stauffer Management Company (SMC) pertaining to the source and distribution of copper and zinc metal loads into Keswick Reservoir. The SMC analyses were included in reports prepared for SMC by Morrison Knudsen Corporation (MK). The first MK report, *Iron Mountain Mine Off-site Metals Loading During 1995 Storm,* dated September 1995, was submitted by SMC as part of its Response to the Water Management Feasibility Study [SMC Vol. 31, Tab 1]. The second MK report was presented in the Declaration of Anne C. Connell in the United States District Court For the Eastern District of California, dated August 29, 1997.

The MK reports estimate the relative contribution of copper and zinc loads into Keswick Reservoir through Spring Creek Debris Dam (SCDD), Shasta Dam, and Spring Creek Powerplant (SCPP). The total Keswick loads are calculated as the sum of the loads from these three sources, with assumptions incorporated into the analyses pertaining to the average copper and zinc concentrations from Shasta Dam and SCPP. The proportion of the Spring Creek load is computed as the Spring Creek load divided by the total Keswick load.

Ms. Connell's declaration states (Page 3, Paragraph 7) " MK's analysis shows that at certain times the water discharged from Shasta is the predominate source of dissolved copper and dissolved zinc loading into Keswick Reservoir. This is true because of the very large volume of water discharged from this source compared with that discharged from the other sources."

The MK analysis fails to mention that on average, the overwhelming copper and zinc loads originate through SCDD. In addition, the MK analyses do not consider the benefit of EPA's Minnesota Flats treatment plant, which was in operation during each of the study periods included in the MK analyses. The treatment plant, which treats acid mine drainage (AMD) discharges from the three largest Iron Mountain Mine (IMM) contaminant sources, has reduced the copper and zinc loads discharged from Iron Mountain by approximately 70 to 90 percent.

This memorandum provides additional computations to show the proportion of the IMM load that would have been present had EPA's treatment plant not been in operation during the study periods. The CH2M HILL spreadsheet analyses are presented in Attachment 1. The MK spreadsheets are presented in Attachment 2. A listing of the loads removed during the study periods by EPA's Minnesota Flats treatment plant is provided in Attachment 3. These treatment plant data were provided electronically by SMC to EPA.

The approach taken by MK is only approximate because the analyses assumes average copper and zinc concentrations for Shasta Dam and SCPP discharges, rather than use actual values. The basic approach provides a reasonable estimate of the distribution of loads during the time periods evaluated.

The analysis presented herein uses the copper and zinc concentrations and loads for Shasta and SCPP discharges that were computed and listed in the MK spreadsheet tabulations. Ms. Connell's 1997 declaration assumed copper concentrations of 1.2 µg/L and 2.1 µg/L for Shasta discharges and assumed copper concentrations of 1.0 µg/L and 2.0 µg/L for SCPP discharges. The analyses presented herein assumes copper concentrations of 1.2 µg/L and 1.0 µg/L for Shasta and SCPP discharges, respectively. Analytical testing of samples obtained from Shasta Dam and SCPP by CH2M HILL shows that these lower concentration values are more representative of the actual observed concentrations than the higher concentration values. A summary of CH2M HILL, SMC, and Regional Water Quality Control Board test results for Shasta Dam discharges and SCPP discharges is provided in Attachment 4.

Analysis of the data shows that the largest source of copper and zinc loads into Keswick Reservoir during the study periods is from the IMM site through SCDD. This is true with and without the treatment plant in place. The analysis shows that if the IMM treatment plant had not been in place, the overwhelming load into Keswick Reservoir would have originated from IMM.

Table 1 provides the average, minimum, and maximum copper and zinc load contributions from SCDD with and without the IMM treatment plant in operation. Table 1 shows that with the IMM treatment plant in operation:

- The average copper contribution from IMM through SCDD for the five study periods ranged from 54.1 percent to 85.8 percent.
- The average zinc contribution from IMM through SCDD for the five study periods ranged from 49.9 percent to 90.5 percent.

Table 1 shows that if the IMM treatment plant had not been in operation:

- The average copper contribution from IMM through SCDD for the five study periods would range from 87.0 percent to 94.9 percent.
- The average zinc contribution from IMM through SCDD for the five study periods would range from 89.3 percent to 97.8 percent.

The analysis shows that if EPA's Minnesota Flats treatment plant had not been in operation during the study period, the average proportion of the copper load discharged though SCDD would have increased from approximately 65 percent to about 90 percent while the average proportion of the zinc load would have increased from approximately 64 percent to about 93 percent.

TABLE 1
Copper and Zinc Load Contributions into Keswick Reservoir through SCDD
Actual Loads and Computed Loads if IMM Treatment Plant Had Not Been in Operation

Time Period		Copper Load (%)		Zinc Load (%)	
		Actual	w/o Plant Operation	Actual	w/o Plant Operation
January 1995	Minimum	63.3	88.1	72.7	94.8
	Average	85.8	94.9	90.5	97.8
	Maximum	98.5	99.5	99.3	99.8
March 1995	Minimum	41.2	86.7	44.7	94.0
	Average	62.9	91.5	67.6	96.3
	Maximum	78.5	98.0	87.9	99.2
February 1996	Minimum	16.2	76.1	26.0	82.7
	Average	58.5	87.4	52.9	89.3
	Maximum	85.4	98.4	89.4	98.1
June 1996	Minimum	47.4	83.8	45.8	89.0
	Average	54.1	87.0	49.9	90.6
	Maximum	58.8	92.6	55.8	93.4
December 25, 1996 - January 8, 1997	Minimum	29.0	77.3	21.3	79.7
	Average	67.9	89.6	61.4	90.8
	Maximum	95.3	98.8	95.1	98.9
Average of Avg Data	Average	65.8	90.1	64.5	93.0

ATTACHMENT 1
DISTRIBUTION OF LOADS INTO KESWICK RESERVOIR WITH IMM TREATMENT PLANT IN OPERATION (ACTUAL) AND COMPUTED LOAD WITHOUT IMM TREATMENT PLANT OPERATING
COPPER LOADS

DATE	GALLONS TREATED	INFLUENT-LB	EFFLUENT-LB	LOAD REMOVED BY TREATMENT-LB	ACTUAL SCDD LOAD-LBS	TOTAL IMM LOAD-LBS	ASSUMED SCPP LOAD-LBS	ASSUMED SHASTA LOAD-LBS	TOTAL LOAD INTO KESWICK W/TREATMENT-LB	TOTAL LOAD INTO KESWICK W/O TREATMENT-LB	% CONTRIBUTION INTO KESWICK W/ TREATMENT PLANT OPERATING			% CONTRIBUTION INTO KESWICK W/O TREATMENT PLANT OPERATING		
											SHASTA	SCPP	SCDD	SHASTA	SCPP	SCDD
1-Jan-95	149,760	160.0	0.025	160.0					0.0	0.0						
2-Jan-95	156,096	168.0	0.026	168.0					0.0	0.0						
3-Jan-95	156,096	173.3	0.026	173.2	122.0	295.2	2.0	38.0	335.2	162.0	23.5%	1.2%	75.3%	11.3%	0.6%	88.1%
4-Jan-95	158,112	176.8	0.026	176.8					0.0	0.0						
5-Jan-95	158,112	174.2	0.026	174.1					0.0	0.0						
6-Jan-95	158,112	171.5	0.104	171.4	119.0	290.4	2.0	34.0	326.4	155.0	21.9%	1.3%	76.8%	10.4%	0.6%	89.0%
7-Jan-95	166,032	181.5	0.036	181.5					0.0	0.0						
8-Jan-95	175,536	218.3	0.029	218.2					0.0	0.0						
9-Jan-95	964,515	1,730.6	0.161	1,730.4	789.0	2,519.4	18.0	3.0	2,540.4	810.0	0.4%	2.2%	97.4%	0.1%	0.7%	99.2%
10-Jan-95	1,664,400	7,764.6	0.278	7,764.3	977.0	8,741.3	28.0	20.0	8,789.3	1,025.0	2.0%	2.7%	95.3%	0.2%	0.3%	99.5%
11-Jan-95	1,389,600	5,682.5			1,364.0		29.0	35.0	64.0	1,428.0	2.5%	2.0%	95.5%			
12-Jan-95	1,507,560	4,579.6			3,101.0		28.0	21.0	49.0	3,150.0	0.7%	0.9%	98.4%			
13-Jan-95	1,182,750	3,356.0	0.207	3,355.8	4,356.0	7,711.8	31.0	35.0	7,777.8	4,422.0	0.8%	0.7%	98.5%	0.4%	0.4%	99.2%
14-Jan-95	1,975,490	5,341.6	0.330	5,341.3	2,792.0	8,133.3	28.0	38.0	8,199.3	2,858.0	1.3%	1.0%	97.7%	0.5%	0.3%	99.2%
15-Jan-95	1,440,000	3,617.3	0.240	3,617.0	1,209.0	4,826.0	29.0	94.0	4,949.0	1,332.0	7.1%	2.2%	90.8%	1.9%	0.6%	97.5%
16-Jan-95	1,224,000	3,044.0	0.378	3,043.6	1,643.0	4,686.6	27.0	104.0	4,817.6	1,774.0	5.9%	1.5%	92.6%	2.2%	0.6%	97.3%
17-Jan-95	972,000	2,474.1	0.446	2,473.6	1,663.0	4,136.6	28.0	130.0	4,294.6	1,821.0	7.1%	1.5%	91.3%	3.0%	0.7%	96.3%
18-Jan-95	864,000	2,314.6	0.224	2,314.3	1,732.0	4,046.3	28.0	197.0	4,271.3	1,957.0	10.1%	1.4%	88.5%	4.6%	0.7%	94.7%
19-Jan-95	806,400	2,220.8	0.155	2,220.7	2,020.0	4,240.7	27.0	334.0	4,601.7	2,381.0	14.0%	1.1%	84.8%	7.3%	0.6%	92.2%
20-Jan-95	748,800	2,068.4	0.287	2,068.2	1,051.0	3,119.2	28.0	335.0	3,482.2	1,414.0	23.7%	2.0%	74.3%	9.6%	0.8%	89.6%
21-Jan-95	698,400	1,935.1	0.175	1,934.9					0.0	0.0						
22-Jan-95	576,000	1,639.2	0.202	1,639.0					0.0	0.0						
23-Jan-95	504,000	1,467.9	0.151	1,467.8	503.0	1,970.8	28.0	102.0	2,100.8	633.0	16.1%	4.4%	79.5%	4.9%	1.3%	93.8%
24-Jan-95	685,440	1,647.4	0.200	1,647.2					0.0	0.0						
25-Jan-95	1,035,360	2,445.3	3.024	2,442.3	242.0	2,684.3	28.0	82.0	2,794.3	352.0	23.3%	8.0%	68.8%	2.9%	1.0%	96.1%
26-Jan-95	1,051,200	2,614.3	1.316	2,613.0					0.0	0.0						
27-Jan-95	829,440	2,402.0	0.900	2,401.1	302.0	2,703.1	27.0	148.0	2,878.1	477.0	31.0%	5.7%	63.3%	5.1%	0.9%	93.9%
28-Jan-95	754,560	2,115.8	0.126	2,115.7					0.0	0.0						
29-Jan-95	851,040	2,365.1	0.142	2,364.9					0.0	0.0						
30-Jan-95	840,960	2,337.1	0.484	2,336.6	769.0	3,105.6	17.0	241.0	3,363.6	1,027.0	23.5%	1.7%	74.9%	7.2%	0.5%	92.3%
31-Jan-95	839,520	2,291.0	0.911	2,290.1	1,285.0	3,575.1	26.0	172.0	3,773.1	1,483.0	11.6%	1.8%	86.6%	4.6%	0.7%	94.8%
										Minimum	0.4%	0.7%	63.3%	0.1%	0.3%	88.1%
										Average	11.9%	2.3%	85.8%	4.5%	0.7%	94.9%
										Maximum	31.0%	8.0%	98.5%	11.3%	1.3%	99.5%

For January 1995 and March 1995 Analyses:

Assumes Shasta copper concentration = 2.0 µg/L

Assumes SCPP copper concentration = 1.2 µg/L

For February 1996, June 1996, and December 1996-January 1997 Analyses:

Assumes Shasta copper concentration = 1.2 µg/L

Assumes SCPP copper concentration = 1.0 µg/L

ATTACHMENT 1
DISTRIBUTION OF LOADS INTO KESWICK RESERVOIR WITH IMM TREATMENT PLANT IN OPERATION (ACTUAL) AND COMPUTED LOAD WITHOUT IMM TREATMENT PLANT OPERATING
COPPER LOADS

DATE	GALLONS TREATED	INFLUENT-LB	EFFLUENT-LB	LOAD REMOVED BY TREATMENT-LB	ACTUAL SCDD LOAD-LBS	TOTAL IMM LOAD-LBS	ASSUMED SCPP LOAD-LBS	ASSUMED SHASTA LOAD-LBS	TOTAL LOAD INTO KESWICK W/TREATMENT-LB	TOTAL LOAD INTO KESWICK W/O TREATMENT-LB	% CONTRIBUTION INTO KESWICK W/ TREATMENT PLANT OPERATING			% CONTRIBUTION INTO KESWICK W/O TREATMENT PLANT OPERATING		
											SHASTA	SCPP	SCDD	SHASTA	SCPP	SCDD
1-Mar-95	506,844	1,362.0	0.085	1,361.9	107.0	1,468.9	2.0	50.0	1,520.9	159.0	31.4%	1.3%	67.3%	3.3%	0.1%	96.6%
2-Mar-95	455,736	1,304.5	0.076	1,304.5	101.0	1,405.5	2.0	47.0	1,454.5	150.0	31.3%	1.3%	67.3%	3.2%	0.1%	96.6%
3-Mar-95	252,590	704.1	0.042	704.0	88.0	792.0	6.0	45.0	843.0	139.0	32.4%	4.3%	63.3%	5.3%	0.7%	94.0%
4-Mar-95	342,450	937.4	0.057	937.3			14.0	17.0	31.0	31.0						
5-Mar-95	347,300	933.3	0.058	933.2			2.0	44.0	46.0	46.0						
6-Mar-95	341,625	895.2	0.057	895.2	70.0	965.2	2.0	46.0	1,013.2	118.0	39.0%	1.7%	59.3%	4.5%	0.2%	95.3%
7-Mar-95	357,800	913.7	0.060	913.7	137.0	1,050.7	2.0	51.0	1,103.7	190.0	26.8%	1.1%	72.1%	4.6%	0.2%	95.2%
8-Mar-95	453,256	1,214.2	0.076	1,214.1	160.0	1,374.1	2.0	48.0	1,424.1	210.0	22.9%	1.0%	76.2%	3.4%	0.1%	96.5%
9-Mar-95	800,680	1,530.2	0.134	1,530.1	124.0	1,654.1	10.0	24.0	1,688.1	158.0	15.2%	6.3%	78.5%	1.4%	0.6%	98.0%
10-Mar-95	1,191,510	2,396.4	0.199	2,396.2	272.0	2,668.2	26.0	95.0	2,789.2	393.0	24.2%	6.6%	69.2%	3.4%	0.9%	95.7%
11-Mar-95	1,464,762	2,860.4	0.318	2,860.1	748.0	3,608.1	26.0	442.0	4,076.1	1,216.0	36.3%	2.1%	61.5%	10.8%	0.6%	88.5%
12-Mar-95	1,392,138	2,811.6	0.558	2,811.0	1,104.0	3,915.0	26.0	544.0	4,485.0	1,674.0	32.5%	1.6%	65.9%	12.1%	0.6%	87.3%
13-Mar-95	1,213,702	2,461.3	0.598	2,460.7	1,266.0	3,726.7	27.0	547.0	4,300.7	1,840.0	29.7%	1.5%	68.8%	12.7%	0.6%	86.7%
14-Mar-95	1,815,296	3,408.6	0.364	3,408.3	1,150.0	4,558.3	27.0	480.0	5,065.3	1,657.0	29.0%	1.6%	69.4%	9.5%	0.5%	90.0%
15-Mar-95	1,287,488	2,804.4	0.258	2,804.1	1,367.0	4,171.1	16.0	610.0	4,797.1	1,993.0	30.6%	0.8%	68.6%	12.7%	0.3%	87.0%
16-Mar-95	1,733,672	4,557.5	0.289	4,557.2	1,508.0	6,065.2	1.0	731.0	6,797.2	2,240.0	32.6%	0.0%	67.3%	10.8%	0.0%	89.2%
17-Mar-95	1,778,464	4,630.7	0.297	4,630.4	1,661.0	6,291.4	14.0	736.0	7,041.4	2,411.0	30.5%	0.6%	68.9%	10.5%	0.2%	89.3%
18-Mar-95	1,647,672	4,661.4	0.275	4,661.2			27.0	723.0	750.0	750.0						
19-Mar-95	1,413,648	3,810.6	0.236	3,810.4			27.0	674.0	701.0	701.0						
20-Mar-95	1,424,572	3,780.6	0.262	3,780.3	1,042.0	4,822.3	27.0	469.0	5,318.3	1,538.0	30.5%	1.8%	67.8%	8.8%	0.5%	90.7%
21-Mar-95	1,424,240	3,708.4	0.238	3,708.2	1,009.0	4,717.2	27.0	485.0	5,229.2	1,521.0	31.9%	1.8%	66.3%	9.3%	0.5%	90.2%
22-Mar-95	1,332,232	3,480.0	0.222	3,479.7	347.0	3,826.7	23.0	473.0	4,322.7	843.0	56.1%	2.7%	41.2%	10.9%	0.5%	88.5%
23-Mar-95	1,383,312	3,371.0	0.231	3,370.7	378.0	3,748.7	27.0	475.0	4,250.7	880.0	54.0%	3.1%	43.0%	11.2%	0.6%	88.2%
24-Mar-95	1,379,652	3,166.3	0.230	3,166.1	414.0	3,580.1	27.0	473.0	4,080.1	914.0	51.8%	3.0%	45.3%	11.6%	0.7%	87.7%
25-Mar-95	1,371,860	3,240.0	0.229	3,239.8			27.0	379.0	406.0	406.0						
26-Mar-95	1,372,056	3,240.5	3.092	3,237.4			13.0	329.0	342.0	342.0						
27-Mar-95	1,373,308	3,025.7	0.321	3,025.4	457.0	3,482.4	4.0	361.0	3,847.4	822.0	43.9%	0.5%	55.6%	9.4%	0.1%	90.5%
28-Mar-95	1,175,940	2,777.3	0.226	2,777.1	337.0	3,114.1	7.0	290.0	3,411.1	634.0	45.7%	1.1%	53.2%	8.5%	0.2%	91.3%
29-Mar-95	934,152	2,120.5	0.187	2,120.3	341.0	2,461.3	6.0	256.0	2,723.3	603.0	42.5%	1.0%	56.6%	9.4%	0.2%	90.4%
30-Mar-95	1,026,648	2,270.5	0.188	2,270.3	353.0	2,623.3	7.0	212.0	2,842.3	572.0	37.1%	1.2%	61.7%	7.5%	0.2%	92.3%
31-Mar-95	861,232	2,026.8	0.144	2,026.7	264.0	2,290.7	5.0	180.0	2,475.7	449.0	40.1%	1.1%	58.8%	7.3%	0.2%	92.5%
										Minimum	15.2%	0.0%	41.2%	1.4%	0.0%	86.7%
										Average	35.1%	2.0%	62.9%	8.1%	0.4%	91.5%
										Maximum	56.1%	6.6%	78.5%	12.7%	0.9%	98.0%

For January 1995 and March 1995 Analyses:

Assumes Shasta copper concentration = 2.0 μg/L

Assumes SCPP copper concentration = 1.2 μg/L

For February 1996, June 1996, and December 1996-January 1997 Analyses:

Assumes Shasta copper concentration = 1.2 μg/L

Assumes SCPP copper concentration = 1.0 μg/L

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DISTRIBUTION OF LOADS INTO KESWICK RESERVOIR WITH IMM TREATMENT PLANT IN OPERATION (ACTUAL)
AND COMPUTED LOAD WITHOUT IMM TREATMENT PLANT OPERATING
COPPER LOADS

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											SHASTA	SCPP	SCDD	SHASTA	SCPP	SCDD
1-Feb-96	268,300	262.0	0.045	261.9	194.2	456.1	9.8	42.1	508.0	246.1	17.1%	4.0%	78.9%	8.3%	1.9%	89.8%
2-Feb-96	320,600	652.8	0.054	652.8	147.3	800.1	9.8	34.4	844.3	191.5	18.0%	5.1%	76.9%	4.1%	1.2%	94.8%
3-Feb-96	344,600	339.3	0.058	339.3	134.6	473.9	2.0	36.9	512.8	173.5	21.3%	1.2%	77.6%	7.2%	0.4%	92.4%
4-Feb-96	353,000	341.7	0.059	341.7	133.8	475.5	6.1	25.4	507.0	165.3	15.4%	3.7%	80.9%	5.0%	1.2%	93.8%
5-Feb-96	410,000	1,170.2	0.068	1,170.1	157.5	1,327.6	9.6	19.9	1,357.1	187.0	10.6%	5.1%	84.2%	1.5%	0.7%	97.8%
6-Feb-96	495,000	3,143.7	0.083	3,143.6	323.1	3,466.7	10.0	46.2	3,522.9	379.3	12.2%	2.6%	85.2%	1.3%	0.3%	98.4%
7-Feb-96	690,800	1,493.1	0.115	1,493.0	373.5	1,866.5	10.2	53.7	1,930.4	437.4	12.3%	2.3%	85.4%	2.8%	0.5%	96.7%
8-Feb-96	522,522	623.6	0.087	623.5	344.3	967.8	10.3	58.5	1,036.6	413.1	14.2%	2.5%	83.3%	5.6%	1.0%	93.4%
9-Feb-96	596,254	1,721.7	0.100	1,721.6	316.5	2,038.1	11.8	48.0	2,097.9	376.3	12.8%	3.1%	84.1%	2.3%	0.6%	97.1%
10-Feb-96	518,052	652.8	0.086	652.7	354.1	1,006.8	12.3	101.3	1,120.4	467.7	21.7%	2.6%	75.7%	9.0%	1.1%	89.9%
11-Feb-96	548,930	1,301.0	0.105	1,300.9	326.2	1,627.1	19.7	110.7	1,757.5	456.6	24.2%	4.3%	71.4%	6.3%	1.1%	92.6%
12-Feb-96	523,106	846.9	0.087	846.8	334.1	1,180.9	19.7	123.0	1,323.6	476.8	25.8%	4.1%	70.1%	9.3%	1.5%	89.2%
13-Feb-96	492,800	666.2	0.082	666.2	231.9	898.1	19.7	178.3	1,096.1	429.9	41.5%	4.6%	53.9%	16.3%	1.8%	81.9%
14-Feb-96	461,618	1,101.8	0.077	1,101.7	264.5	1,366.2	20.1	195.8	1,582.1	480.4	40.8%	4.2%	55.1%	12.4%	1.3%	86.4%
15-Feb-96	438,754	593.2	0.073	593.1	168.6	761.7	21.3	190.9	973.9	380.8	50.1%	5.6%	44.3%	19.6%	2.2%	78.2%
16-Feb-96	399,294	543.2	0.067	543.1	154.0	697.1	21.3	154.4	872.8	329.7	46.8%	6.5%	46.7%	17.7%	2.4%	79.9%
17-Feb-96	326,752	422.7	0.055	422.6	146.7	569.3	21.3	157.1	747.7	325.1	48.3%	6.6%	45.1%	21.0%	2.8%	76.1%
18-Feb-96	474,774	2,222.8	0.079	2,222.7	38.1	2,260.8	21.4	175.4	2,457.6	234.9	74.7%	9.1%	16.2%	7.1%	0.9%	92.0%
19-Feb-96	560,966	781.8	0.094	781.7	131.1	912.8	21.6	200.9	1,135.3	353.6	56.8%	6.1%	37.1%	17.7%	1.9%	80.4%
20-Feb-96	648,806	860.9	0.108	860.8	392.9	1,253.7	21.4	194.6	1,469.7	608.9	32.0%	3.5%	64.5%	13.2%	1.5%	85.3%
21-Feb-96	756,554	2,411.9	0.126	2,411.7	375.4	2,787.1	20.9	213.0	3,021.0	609.3	35.0%	3.4%	61.6%	7.1%	0.7%	92.3%
22-Feb-96	791,996	1,123.6	0.132	1,123.5	480.6	1,604.1	6.3	89.7	1,700.1	576.6	15.6%	1.1%	83.4%	5.3%	0.4%	94.4%
23-Feb-96	715,604	1,045.1	0.119	1,045.0	231.4	1,276.4	6.3	320.5	1,603.2	558.2	57.4%	1.1%	41.5%	20.0%	0.4%	79.6%
24-Feb-96	691,304	1,044.2	0.115	1,044.1	265.4	1,309.5	9.2	336.5	1,655.2	611.1	55.1%	1.5%	43.4%	20.3%	0.6%	79.1%
25-Feb-96	684,410	1,119.5	0.114	1,119.4	252.7	1,372.1	8.9	324.8	1,705.8	586.4	55.4%	1.5%	43.1%	19.0%	0.5%	80.4%
26-Feb-96	685,014	1,097.6	0.114	1,097.5	107.2	1,204.7	9.0	336.7	1,550.4	452.9	74.3%	2.0%	23.7%	21.7%	0.6%	77.7%
27-Feb-96	686,240	1,111.0	0.115	1,110.9	106.6	1,217.5	14.2	296.2	1,527.9	417.0	71.0%	3.4%	25.6%	19.4%	0.9%	79.7%
28-Feb-96	688,553	1,086.0	0.115	1,085.9	137.5	1,223.4	21.1	270.6	1,515.1	429.2	63.0%	4.9%	32.0%	17.9%	1.4%	80.7%
29-Feb-96	683,048	1,100.2	0.114	1,100.1	78.9	1,179.0	21.3	211.4	1,411.7	311.6	67.8%	6.8%	25.3%	15.0%	1.5%	83.5%
										Minimum	10.6%	1.1%	16.2%	1.3%	0.3%	76.1%
										Average	37.6%	3.9%	58.5%	11.5%	1.1%	87.4%
										Maximum	74.7%	9.1%	85.4%	21.7%	2.8%	98.4%

For January 1995 and March 1995 Analyses:
Assumes Shasta copper concentration = 2.0 µg/L
Assumes SCPP copper concentration = 1.2 µg/L
For February 1996, June 1996, and December 1996-January 1997 Analyses:
Assumes Shasta copper concentration = 1.2 µg/L
Assumes SCPP copper concentration = 1.0 µg/L

ATTACHMENT 1

DISTRIBUTION OF LOADS INTO KESWICK RESERVOIR WITH IMM TREATMENT PLANT IN OPERATION (ACTUAL)
AND COMPUTED LOAD WITHOUT IMM TREATMENT PLANT OPERATING
COPPER LOADS

DATE	GALLONS TREATED	INFLUENT-LB	EFFLUENT-LB	LOAD REMOVED BY TREATMENT-LB	ACTUAL SCDD LOAD-LBS	TOTAL IMM LOAD-LBS	ASSUMED SCPP LOAD-LBS	ASSUMED SHASTA LOAD-LBS	TOTAL LOAD INTO KESWICK W/TREATMENT-LB	TOTAL LOAD INTO KESWICK W/O TREATMENT-LB	% CONTRIBUTION INTO KESWICK W/ TREATMENT PLANT OPERATING			% CONTRIBUTION INTO KESWICK W/O TREATMENT PLANT OPERATING		
											SHASTA	SCPP	SCDD	SHASTA	SCPP	SCDD
1-Jun-96	293,167	442.8	0.049	442.8			5.4	84.1	89.5	89.5						
2-Jun-96	291,525	442.8	0.049	442.7			4.9	79.1	84.0	84.0						
3-Jun-96	291,254	461.8	0.049	461.8			4.9	92.2	97.1	97.1						
4-Jun-96	365,916	1,035.2	0.061	1,035.2	89.5	1,124.7	5.1	84.2	1,214.0	178.8	47.1%	2.9%	50.1%	6.9%	0.4%	92.6%
5-Jun-96	326,780	790.9	0.055	790.8	90.0	880.8	7.9	92.1	980.8	190.0	48.5%	4.2%	47.4%	9.4%	0.8%	89.8%
6-Jun-96	328,358	800.2	0.055	800.1			7.2	92.6	99.8	99.8						
7-Jun-96	313,200	713.6	0.052	713.5			11.0	90.2	101.2	101.2						
8-Jun-96	278,800	430.4	0.047	430.4			10.8	79.8	90.6	90.6						
9-Jun-96	277,200	409.5	0.046	409.4			10.9	88.7	99.6	99.6						
10-Jun-96	323,400	480.4	0.054	480.4			10.7	81.6	92.3	92.3						
11-Jun-96	307,700	644.5	0.051	644.5			10.7	78.2	88.9	88.9						
12-Jun-96	278,500	404.4	0.046	404.4	113.8	518.2	11.1	77.1	606.4	202.0	38.2%	5.5%	56.3%	12.7%	1.8%	85.5%
13-Jun-96	284,247	403.3	0.047	403.2			10.1	77.4	87.5	87.5						
14-Jun-96	272,638	391.3	0.046	391.3			10.2	82.2	92.4	92.4						
15-Jun-96	257,343	365.1	0.043	365.1			16.9	73.1	90.0	90.0						
16-Jun-96	253,178	352.9	0.042	352.8			15.6	74.7	90.3	90.3						
17-Jun-96	234,735	329.1	0.039	329.1			15.6	68.2	83.8	83.8						
18-Jun-96	258,183	349.1	0.043	349.0	120.8	469.8	15.5	75.2	560.5	211.5	35.6%	7.3%	57.1%	13.4%	2.8%	83.8%
19-Jun-96	256,716	349.2	0.043	349.2	111.1	460.3	15.5	62.3	538.1	188.9	33.0%	8.2%	58.8%	11.6%	2.9%	85.5%
20-Jun-96	257,787	361.4	0.043	361.4			15.6	70.1	85.7	85.7						
21-Jun-96	213,150	334.4	0.036	334.4			15.9	61.0	76.9	76.9						
22-Jun-96	149,085	265.0	0.025	265.0			15.8	68.6	84.4	84.4						
23-Jun-96	160,611	266.7	0.027	266.7			15.5	66.7	82.2	82.2						
24-Jun-96	189,559	292.7	0.032	292.6			16.0	65.9	81.9	81.9						
25-Jun-96	257,298	341.4	0.043	341.4			15.9	54.1	70.0	70.0						
26-Jun-96	255,217	332.3	0.043	332.2	92.9	425.1	18.3	58.5	501.9	169.7	34.5%	10.8%	54.7%	11.7%	3.6%	84.7%
27-Jun-96	215,458	311.1	0.036	311.0			17.6	61.9	79.5	79.5						
28-Jun-96	195,933	284.5	0.033	284.5			17.5	61.8	79.3	79.3						
29-Jun-96	257,748	333.4	0.043	333.4			18.2	62.2	80.4	80.4						
30-Jun-96	257,556	335.3	0.043	335.3			18.2	67.3	85.5	85.5						
										Minimum	33.0%	2.9%	47.4%	6.9%	0.4%	83.8%
										Average	39.5%	6.5%	54.1%	10.9%	2.1%	87.0%
										Maximum	48.5%	10.8%	58.8%	13.4%	3.6%	92.6%

For January 1995 and March 1995 Analyses:

Assumes Shasta copper concentration = 2.0 µg/L

Assumes SCPP copper concentration = 1.2 µg/L

For February 1996, June 1996, and December 1996-January 1997 Analyses:

Assumes Shasta copper concentration = 1.2 µg/L

Assumes SCPP copper concentration = 1.0 µg/L

ATTACHMENT 1

DISTRIBUTION OF LOADS INTO KESWICK RESERVOIR WITH IMM TREATMENT PLANT IN OPERATION (ACTUAL) AND COMPUTED LOAD WITHOUT IMM TREATMENT PLANT OPERATING

COPPER LOADS

DATE	GALLONS TREATED	INFLUENT-LB	EFFLUENT-LB	LOAD REMOVED BY TREATMENT-LB	ACTUAL SCDD LOAD-LBS	TOTAL IMM LOAD-LBS	ASSUMED SCPP LOAD-LBS	ASSUMED SHASTA LOAD-LBS	TOTAL LOAD INTO KESWICK W/TREATMENT-LB	TOTAL LOAD INTO KESWICK W/O TREATMENT-LB	% CONTRIBUTION INTO KESWICK W/ TREATMENT PLANT OPERATING			% CONTRIBUTION INTO KESWICK W/O TREATMENT PLANT OPERATING		
											SHASTA	SCPP	SCDD	SHASTA	SCPP	SCDD
25-Dec-96	299264	379.6	0.050	379.6			3.1	70.3	73.4	73.4						
26-Dec-96	302788	366.4	0.051	366.4	50.9	417.3	3.1	63.0	483.4	117.0	53.8%	2.6%	43.5%	13.0%	0.6%	86.3%
27-Dec-96	300371	350.9	0.050	350.9	47.8	398.7	3.1	113.9	515.7	164.8	69.1%	1.9%	29.0%	22.1%	0.6%	77.3%
28-Dec-96	312879	362.9	0.052	362.9			5.2	156.4	161.6	161.6						
29-Dec-96	348681	404.5	0.058	404.4	652.7	1,057.1	14.1	235.8	1,307.0	902.6	26.1%	1.6%	72.3%	18.0%	1.1%	80.9%
30-Dec-96	488269	517.5	0.081	517.4	645.6	1,163.0	20.6	262.8	1,446.4	929.0	28.3%	2.2%	69.5%	18.2%	1.4%	80.4%
31-Dec-96	1559571	2,043.4	0.260	2,043.1	558.3	2,601.4	20.2	135.7	2,757.3	714.2	19.0%	2.8%	78.2%	4.9%	0.7%	94.3%
1-Jan-97	2036700	4,368.3	0.340	4,367.9	1,449.0	5,816.9	19.0	52.8	5,888.7	1,520.8	3.5%	1.2%	95.3%	0.9%	0.3%	98.8%
2-Jan-97	2530300	5,891.5	0.887	5,890.6	2,318.1	8,208.7	1.6	278.7	8,489.0	2,598.4	10.7%	0.1%	89.2%	3.3%	0.0%	96.7%
3-Jan-97	2146000	6,572.7	0.358	6,572.4	1,373.4	7,945.8	10.3	419.3	8,375.4	1,803.0	23.3%	0.6%	76.2%	5.0%	0.1%	94.9%
4-Jan-97	1497500	4,386.6	0.250	4,386.3	991.5	5,377.8	21.4	479.6	5,878.8	1,492.5	32.1%	1.4%	66.4%	8.2%	0.4%	91.5%
5-Jan-97	1239500	3,517.0	0.228	3,516.8	890.4	4,407.2	19.9	405.5	4,832.6	1,315.8	30.8%	1.5%	67.7%	8.4%	0.4%	91.2%
6-Jan-97	1083500	3,002.0	0.181	3,001.9	762.3	3,764.2	20.0	284.4	4,068.6	1,066.7	26.7%	1.9%	71.5%	7.0%	0.5%	92.5%
7-Jan-97	995500	2,509.0	0.166	2,508.8	547.3	3,056.1	20.1	299.3	3,375.5	866.7	34.5%	2.3%	63.1%	8.9%	0.6%	90.5%
8-Jan-97	954000	2,300.9	0.159	2,300.7	498.9	2,799.6	13.4	315.0	3,128.0	827.3	38.1%	1.6%	60.3%	10.1%	0.4%	89.5%
										Minimum	3.5%	0.1%	29.0%	0.9%	0.0%	77.3%
										Average	30.5%	1.7%	67.9%	9.8%	0.6%	89.6%
										Maximum	69.1%	2.8%	95.3%	22.1%	1.4%	98.8%

For January 1995 and March 1995 Analyses:

Assumes Shasta copper concentration = 2.0 µg/L

Assumes SCPP copper concentration = 1.2 µg/L

For February 1996, June 1996, and December 1996-January 1997 Analyses:

Assumes Shasta copper concentration = 1.2 µg/L

Assumes SCPP copper concentration = 1.0 µg/L

ATTACHMENT 1

DISTRIBUTION OF LOADS INTO KESWICK RESERVOIR WITH IMM TREATMENT PLANT IN OPERATION (ACTUAL)
AND COMPUTED LOAD WITHOUT IMM TREATMENT PLANT OPERATING
ZINC LOADS

DATE	GALLONS TREATED	INFLUENT-LB	EFFLUENT-LB	LOAD REMOVED BY TREATMENT-LB	ACTUAL SCDD LOAD-LBS	TOTAL LOAD-LBS	ASSUMED SCPP LOAD-LBS	ASSUMED SHASTA LOAD-LBS	TOTAL LOAD INTO KESWICK W/TREATMENT-LB	TOTAL LOAD INTO KESWICK W/O TREATMENT-LB	% CONTRIBUTION INTO KESWICK W/ TREATMENT PLANT OPERATING			% CONTRIBUTION INTO KESWICK W/O TREATMENT PLANT OPERATING		
											SHASTA	SCPP	SCDD	SHASTA	SCPP	SCDD
1-Jan-95	149,760	669.9	0.025	669.9					0.0	0.0						
2-Jan-95	156,096	710.0	0.026	709.9					0.0	0.0						
3-Jan-95	156,096	750.4	0.026	750.3	235.0	985.3	2.0	38.0	1,025.3	275.0	13.8%	0.7%	85.5%	3.7%	0.2%	96.1%
4-Jan-95	158,112	768.0	0.030	767.9					0.0	0.0						
5-Jan-95	158,112	738.9	0.059	738.9					0.0	0.0						
6-Jan-95	158,112	736.3	3.695	732.6	230.0	962.6	2.0	34.0	998.6	266.0	12.8%	0.8%	86.5%	3.4%	0.2%	96.4%
7-Jan-95	166,032	731.6	0.901	730.7					0.0	0.0						
8-Jan-95	175,536	742.7	0.062	742.7					0.0	0.0						
9-Jan-95	964,515	5,811.6	0.636	5,811.0	1,659.0	7,470.0	18.0	3.0	7,491.0	1,680.0	0.2%	1.1%	98.8%	0.0%	0.2%	99.7%
10-Jan-95	1,664,400	18,335.0	0.278	18,334.8	1,854.0	20,188.8	28.0	20.0	20,236.8	1,902.0	1.1%	1.5%	97.5%	0.1%	0.1%	99.8%
11-Jan-95	1,389,600	12,872.5			2,790.0		29.0	35.0	64.0	2,854.0	1.2%	1.0%	97.8%			
12-Jan-95	1,507,560	9,649.8			6,014.0		28.0	21.0	49.0	6,063.0	0.3%	0.5%	99.2%			
13-Jan-95	1,182,750	7,304.2	0.750	7,303.5	9,431.0	16,734.5	31.0	35.0	16,800.5	9,497.0	0.4%	0.3%	99.3%	0.2%	0.2%	99.6%
14-Jan-95	1,975,490	12,414.2	1.105	12,413.1	4,474.0	16,887.1	28.0	38.0	16,953.1	4,540.0	0.8%	0.6%	98.5%	0.2%	0.2%	99.6%
15-Jan-95	1,440,000	9,073.2	0.901	9,072.3	2,051.0	11,123.3	29.0	94.0	11,246.3	2,174.0	4.3%	1.3%	94.3%	0.8%	0.3%	98.9%
16-Jan-95	1,224,000	7,875.6	7.365	7,868.3	3,089.0	10,957.3	27.0	104.0	11,088.3	3,220.0	3.2%	0.8%	95.9%	0.9%	0.2%	98.8%
17-Jan-95	972,000	6,319.1	23.281	6,295.8	2,771.0	9,066.8	28.0	130.0	9,224.8	2,929.0	4.4%	1.0%	94.6%	1.4%	0.3%	98.3%
18-Jan-95	864,000	5,681.9	0.793	5,681.1	2,769.0	8,450.1	28.0	197.0	8,675.1	2,994.0	6.6%	0.9%	92.5%	2.3%	0.3%	97.4%
19-Jan-95	806,400	5,336.7	1.077	5,335.6	3,252.0	8,587.6	27.0	334.0	8,948.6	3,613.0	9.2%	0.7%	90.0%	3.7%	0.3%	96.0%
20-Jan-95	748,800	4,899.3	1.562	4,897.7	1,700.0	6,597.7	28.0	335.0	6,960.7	2,063.0	16.2%	1.4%	82.4%	4.8%	0.4%	94.8%
21-Jan-95	698,400	4,575.3	0.699	4,574.6					0.0	0.0						
22-Jan-95	576,000	4,095.6	1.009	4,094.5					0.0	0.0						
23-Jan-95	504,000	3,987.4	0.883	3,986.5	834.0	4,820.5	28.0	102.0	4,950.5	964.0	10.6%	2.9%	86.5%	2.1%	0.6%	97.4%
24-Jan-95	685,440	4,078.6	1.144	4,077.4					0.0	0.0						
25-Jan-95	1,035,360	6,212.6	7.517	6,205.0	386.0	6,591.0	28.0	82.0	6,701.0	496.0	16.5%	5.6%	77.8%	1.2%	0.4%	98.4%
26-Jan-95	1,051,200	6,930.5	3.597	6,926.9					0.0	0.0						
27-Jan-95	829,440	7,268.2	2.284	7,265.9	466.0	7,731.9	27.0	148.0	7,906.9	641.0	23.1%	4.2%	72.7%	1.9%	0.3%	97.8%
28-Jan-95	754,560	5,724.1	0.132	5,724.0					0.0	0.0						
29-Jan-95	851,040	6,029.9	0.206	6,029.7					0.0	0.0						
30-Jan-95	840,960	5,825.1	1.123	5,824.0	1,057.0	6,881.0	17.0	241.0	7,139.0	1,315.0	18.3%	1.3%	80.4%	3.4%	0.2%	96.4%
31-Jan-95	839,520	5,703.0	2.382	5,700.6	1,685.0	7,385.6	26.0	172.0	7,583.6	1,883.0	9.1%	1.4%	89.5%	2.3%	0.3%	97.4%
										Minimum	0.2%	0.3%	72.7%	0.0%	0.1%	94.8%
										Average	8.0%	1.5%	90.5%	1.9%	0.3%	97.8%
										Maximum	23.1%	5.6%	99.3%	4.8%	0.6%	99.8%

For January 1995 and March 1995 Analyses:

Assumes Shasta zinc concentration = 3.6 µg/L

Assumes SCPP zinc concentration = 3.3 µg/L

For February 1996, June 1996, and December 1996-January 1997 Analyses:

Assumes Shasta zinc concentration = 2.7 µg/L

Assumes SCPP zinc concentration = 2.6 µg/L

ATTACHMENT 1

DISTRIBUTION OF LOADS INTO KESWICK RESERVOIR WITH IMM TREATMENT PLANT IN OPERATION (ACTUAL)

AND COMPUTED LOAD WITHOUT IMM TREATMENT PLANT OPERATING

ZINC LOADS

DATE	GALLONS TREATED	INFLUENT-LB	EFFLUENT-LB	LOAD REMOVED BY TREATMENT-LB	ACTUAL SCDD LOAD-LBS	TOTAL LOAD-LBS	ASSUMED SCPP LOAD-LBS	ASSUMED SHASTA LOAD-LBS	TOTAL LOAD INTO KESWICK W/TREATMENT-LB	TOTAL LOAD INTO KESWICK W/O TREATMENT-LB	% CONTRIBUTION INTO KESWICK W/ TREATMENT PLANT OPERATING			% CONTRIBUTION INTO KESWICK W/O TREATMENT PLANT OPERATING		
											SHASTA	SCPP	SCDD	SHASTA	SCPP	SCDD
1-Mar-95	506,844	2,719.8	0.085	2,719.7	157.0	2,876.7	2.0	50.0	2,928.7	209.0	23.9%	1.0%	75.1%	1.7%	0.1%	98.2%
2-Mar-95	455,736	3,255.6	0.076	3,255.6	148.0	3,403.6	2.0	47.0	3,452.6	197.0	23.9%	1.0%	75.1%	1.4%	0.1%	98.6%
3-Mar-95	252,590	1,462.9	0.042	1,462.9	143.0	1,605.9	6.0	45.0	1,656.9	194.0	23.2%	3.1%	73.7%	2.7%	0.4%	96.9%
4-Mar-95	342,450	1,983.4	0.057	1,983.3			14.0	17.0	31.0	31.0						
5-Mar-95	347,300	2,002.8	0.058	2,002.7			2.0	44.0	46.0	46.0						
6-Mar-95	341,625	1,941.5	0.057	1,941.5	112.0	2,053.5	2.0	46.0	2,101.5	160.0						
7-Mar-95	357,800	1,946.9	0.060	1,946.8	217.0	2,163.8	2.0	51.0	2,216.8	270.0	18.9%	0.7%	80.4%	2.3%	0.1%	97.6%
8-Mar-95	453,256	3,442.2	0.076	3,442.1	264.0	3,706.1	2.0	48.0	3,756.1	314.0	15.3%	0.6%	84.1%	1.3%	0.1%	98.7%
9-Mar-95	800,680	3,935.7	0.134	3,935.6	248.0	4,183.6	10.0	24.0	4,217.6	282.0	8.5%	3.5%	87.9%	0.6%	0.2%	99.2%
10-Mar-95	1,191,510	6,990.4	0.945	6,989.5	521.0	7,510.5	26.0	95.0	7,631.5	642.0	14.8%	4.0%	81.2%	1.2%	0.3%	98.4%
11-Mar-95	1,464,762	9,119.2	5.134	9,114.1	1,233.0	10,347.1	26.0	442.0	10,815.1	1,701.0	26.0%	1.5%	72.5%	4.1%	0.2%	95.7%
12-Mar-95	1,392,138	8,783.2	12.780	8,770.4	1,385.0	10,155.4	26.0	544.0	10,725.4	1,955.0	27.8%	1.3%	70.8%	5.1%	0.2%	94.7%
13-Mar-95	1,213,702	7,444.7	11.142	7,433.6	1,536.0	8,969.6	27.0	547.0	9,543.6	2,110.0	25.9%	1.3%	72.8%	5.7%	0.3%	94.0%
14-Mar-95	1,815,296	10,877.3	7.423	10,869.9	1,353.0	12,222.9	27.0	480.0	12,729.9	1,860.0	25.8%	1.5%	72.7%	3.8%	0.2%	96.0%
15-Mar-95	1,287,488	8,756.9	3.009	8,753.9	1,434.0	10,187.9	16.0	610.0	10,813.9	2,060.0	29.6%	0.8%	69.6%	5.6%	0.1%	94.2%
16-Mar-95	1,733,672	13,701.5	1.592	13,699.9	1,609.0	15,308.9	1.0	731.0	16,040.9	2,341.0	31.2%	0.0%	68.7%	4.6%	0.0%	95.4%
17-Mar-95	1,778,464	13,521.1	1.633	13,519.5	1,628.0	15,147.5	14.0	736.0	15,897.5	2,378.0	31.0%	0.6%	68.5%	4.6%	0.1%	95.3%
18-Mar-95	1,647,672	14,438.1	2.200	14,435.9			27.0	723.0	750.0	750.0						
19-Mar-95	1,413,648	11,172.3	1.770	11,170.5			27.0	674.0	701.0	701.0						
20-Mar-95	1,424,572	10,616.6	1.308	10,615.3	1,369.0	11,984.3	27.0	469.0	12,480.3	1,865.0	25.1%	1.4%	73.4%	3.8%	0.2%	96.0%
21-Mar-95	1,424,240	10,424.0	1.189	10,422.8	1,407.0	11,829.8	27.0	485.0	12,341.8	1,919.0	25.3%	1.4%	73.3%	3.9%	0.2%	95.9%
22-Mar-95	1,332,232	10,350.9	0.656	10,350.3	425.0	10,775.3	23.0	473.0	11,271.3	921.0	51.4%	2.5%	46.1%	4.2%	0.2%	95.6%
23-Mar-95	1,383,312	9,604.9	1.120	9,603.8	406.0	10,009.8	27.0	475.0	10,511.8	908.0	52.3%	3.0%	44.7%	4.5%	0.3%	95.2%
24-Mar-95	1,379,652	9,015.3	1.013	9,014.3	413.0	9,427.3	27.0	473.0	9,927.3	913.0	51.8%	3.0%	45.2%	4.8%	0.3%	95.0%
25-Mar-95	1,371,860	9,056.0	0.756	9,055.2			27.0	379.0	406.0	406.0						
26-Mar-95	1,372,056	9,068.7	9.389	9,059.4			13.0	329.0	342.0	342.0						
27-Mar-95	1,373,308	8,274.8	2.980	8,271.8	447.0	8,718.8	4.0	361.0	9,083.8	812.0	44.5%	0.5%	55.0%	4.0%	0.0%	96.0%
28-Mar-95	1,175,940	7,566.4	2.748	7,563.7	337.0	7,900.7	7.0	290.0	8,197.7	634.0	45.7%	1.1%	53.2%	3.5%	0.1%	96.4%
29-Mar-95	934,152	5,574.1	2.183	5,571.9	347.0	5,918.9	6.0	256.0	6,180.9	609.0	42.0%	1.0%	57.0%	4.1%	0.1%	95.8%
30-Mar-95	1,026,648	5,886.1	1.114	5,885.0	359.0	6,244.0	7.0	212.0	6,463.0	578.0	36.7%	1.2%	62.1%	3.3%	0.1%	96.6%
31-Mar-95	861,232	5,721.2	0.654	5,720.5	275.0	5,995.5	5.0	180.0	6,180.5	460.0	39.1%	1.1%	59.8%	2.9%	0.1%	97.0%
										Minimum	8.5%	0.0%	44.7%	0.6%	0.0%	94.0%
										Average	30.8%	1.5%	67.6%	3.5%	0.2%	96.3%
										Maximum	52.3%	4.0%	87.9%	5.7%	0.4%	99.2%

For January 1995 and March 1995 Analyses:

Assumes Shasta zinc concentration = 3.6 μg/L

Assumes SCPP zinc concentration = 3.3 μg/L

For February 1996, June 1996, and December 1996-January 1997 Analyses:

Assumes Shasta zinc concentration = 2.7 μg/L

Assumes SCPP zinc concentration = 2.6 μg/L

ATTACHMENT 1

DISTRIBUTION OF LOADS INTO KESWICK RESERVOIR WITH IMM TREATMENT PLANT IN OPERATION (ACTUAL) AND COMPUTED LOAD WITHOUT IMM TREATMENT PLANT OPERATING

ZINC LOADS

DATE	GALLONS TREATED	INFLUENT-LB	EFFLUENT-LB	LOAD REMOVED BY TREATMENT-LB	ACTUAL SCDD LOAD-LBS	TOTAL LOAD-LBS	ASSUMED SCPP LOAD-LBS	ASSUMED SHASTA LOAD-LBS	TOTAL LOAD INTO KESWICK W/TREATMENT-LB	TOTAL LOAD INTO KESWICK W/O TREATMENT-LB	% CONTRIBUTION INTO KESWICK W/ TREATMENT PLANT OPERATING			% CONTRIBUTION INTO KESWICK W/O TREATMENT PLANT OPERATING		
											SHASTA	SCPP	SCDD	SHASTA	SCPP	SCDD
1-Feb-96	268,300	991.9	0.069	991.8	288.4	1,280.2	25.4	94.7	1,400.3	408.5	23.2%	6.2%	70.6%	6.8%	1.8%	91.4%
2-Feb-96	320,600	1,300.3	0.054	1,300.3	213.4	1,513.7	25.5	77.3	1,616.5	316.2	24.4%	8.1%	67.5%	4.8%	1.6%	93.6%
3-Feb-96	344,600	1,397.7	0.069	1,397.6	187.9	1,585.5	5.1	82.9	1,673.5	275.9	30.0%	1.8%	68.1%	5.0%	0.3%	94.7%
4-Feb-96	353,000	1,402.3	0.106	1,402.2	196.6	1,598.8	15.9	57.2	1,671.9	269.7	21.2%	5.9%	72.9%	3.4%	1.0%	95.6%
5-Feb-96	410,000	1,912.7	0.075	1,912.6	224.0	2,136.6	25.0	44.8	2,206.4	293.8	15.2%	8.5%	76.2%	2.0%	1.1%	96.8%
6-Feb-96	495,000	2,466.2	0.083	2,466.1	448.2	2,914.3	26.0	104.0	3,044.3	578.2	18.0%	4.5%	77.5%	3.4%	0.9%	95.7%
7-Feb-96	690,800	3,303.4	0.115	3,303.3	527.2	3,830.5	26.6	120.8	3,977.9	674.6	17.9%	3.9%	78.2%	3.0%	0.7%	96.3%
8-Feb-96	522,522	2,428.9	0.100	2,428.8	447.3	2,876.1	26.9	131.6	3,034.6	605.8	21.7%	4.4%	73.8%	4.3%	0.9%	94.8%
9-Feb-96	596,254	2,692.0	0.179	2,691.8	403.2	3,095.0	30.6	108.0	3,233.6	541.8	19.9%	5.6%	74.4%	3.3%	0.9%	95.7%
10-Feb-96	518,052	2,408.1	0.233	2,407.9	462.8	2,870.7	31.9	22.9	2,925.5	517.6	4.4%	6.2%	89.4%	0.8%	1.1%	98.1%
11-Feb-96	548,930	2,492.1	0.279	2,491.8	451.8	2,943.6	51.3	249.0	3,243.9	752.1	33.1%	6.8%	60.1%	7.7%	1.6%	90.7%
12-Feb-96	523,106	2,388.0	0.140	2,387.8	474.0	2,861.8	51.2	276.8	3,189.8	802.0	34.5%	6.4%	59.1%	8.7%	1.6%	89.7%
13-Feb-96	492,800	2,352.4	0.140	2,352.3	303.6	2,655.9	51.2	401.3	3,108.4	756.1	53.1%	6.8%	40.2%	12.9%	1.6%	85.4%
14-Feb-96	461,618	2,141.9	0.112	2,141.8	355.6	2,497.4	52.4	440.4	2,990.2	848.4	51.9%	6.2%	41.9%	14.7%	1.8%	83.5%
15-Feb-96	438,754	2,065.1	0.139	2,065.0	245.7	2,310.7	55.3	429.5	2,795.5	730.5	58.8%	7.6%	33.6%	15.4%	2.0%	82.7%
16-Feb-96	399,294	1,866.1	0.107	1,866.0	266.2	2,132.2	55.3	347.4	2,534.9	668.9	51.9%	8.3%	39.8%	13.7%	2.2%	84.1%
17-Feb-96	326,752	1,649.8	0.063	1,649.7	329.0	1,978.7	55.3	353.6	2,387.6	737.9	47.9%	7.5%	44.6%	14.8%	2.3%	82.9%
18-Feb-96	474,774	2,329.8	0.083	2,329.7	158.4	2,488.1	55.6	394.7	2,938.4	608.7	64.8%	9.1%	26.0%	13.4%	1.9%	84.7%
19-Feb-96	560,966	2,499.9	0.126	2,499.8	237.2	2,737.0	56.2	452.1	3,245.3	745.5	60.6%	7.5%	31.8%	13.9%	1.7%	84.3%
20-Feb-96	648,806	3,048.4	0.141	3,048.3	555.7	3,604.0	55.5	437.9	4,097.4	1,049.1	41.7%	5.3%	53.0%	10.7%	1.4%	88.0%
21-Feb-96	756,554	3,939.8	0.152	3,939.7	532.4	4,472.1	54.4	479.2	5,005.7	1,066.0	45.0%	5.1%	49.9%	9.6%	1.1%	89.3%
22-Feb-96	791,996	4,018.6	0.165	4,018.5	632.7	4,651.2	16.4	201.8	4,869.4	850.9	23.7%	1.9%	74.4%	4.1%	0.3%	95.5%
23-Feb-96	715,604	3,762.4	0.137	3,762.2	328.5	4,090.7	16.5	721.2	4,828.4	1,066.2	67.6%	1.5%	30.8%	14.9%	0.3%	84.7%
24-Feb-96	691,304	3,750.0	0.121	3,749.9	380.3	4,130.2	23.9	757.2	4,911.3	1,161.4	65.2%	2.1%	32.7%	15.4%	0.5%	84.1%
25-Feb-96	684,410	3,741.2	0.126	3,741.0	401.8	4,142.8	23.2	730.8	4,896.8	1,155.8	63.2%	2.0%	34.8%	14.9%	0.5%	84.6%
26-Feb-96	685,014	3,807.4	0.149	3,807.2	315.1	4,122.3	23.4	757.6	4,903.3	1,096.1	69.1%	2.1%	28.7%	15.5%	0.5%	84.1%
27-Feb-96	686,240	3,774.1	0.115	3,774.0	406.6	4,180.6	36.9	666.5	4,884.0	1,110.0	60.0%	3.3%	36.6%	13.6%	0.8%	85.6%
28-Feb-96	688,553	3,689.1	0.115	3,689.0	416.7	4,105.7	55.0	608.8	4,769.5	1,080.5	56.3%	5.1%	38.6%	12.8%	1.2%	86.1%
29-Feb-96	683,048	3,705.2	0.114	3,705.1	228.1	3,933.2	55.3	475.7	4,464.2	759.1	62.7%	7.3%	30.0%	10.7%	1.2%	88.1%
										Minimum	4.4%	1.5%	26.0%	0.8%	0.3%	82.7%
										Average	41.6%	5.4%	52.9%	9.5%	1.2%	89.3%
										Maximum	69.1%	9.1%	89.4%	15.5%	2.3%	98.1%

For January 1995 and March 1995 Analyses:

Assumes Shasta zinc concentration = 3.6 µg/L

Assumes SCPP zinc concentration = 3.3 µg/L

For February 1996, June 1996, and December 1996-January 1997 Analyses:

Assumes Shasta zinc concentration = 2.7 µg/L

Assumes SCPP zinc concentration = 2.6 µg/L

ATTACHMENT 1
DISTRIBUTION OF LOADS INTO KESWICK RESERVOIR WITH IMM TREATMENT PLANT IN OPERATION (ACTUAL) AND COMPUTED LOAD WITHOUT IMM TREATMENT PLANT OPERATING
ZINC LOADS

DATE	GALLONS TREATED	INFLUENT-LB	EFFLUENT-LB	LOAD REMOVED BY TREATMENT-LB	ACTUAL SCDD LOAD-LBS	TOTAL LOAD-LBS	ASSUMED SCPP LOAD-LBS	ASSUMED SHASTA LOAD-LBS	TOTAL LOAD INTO KESWICK W/TREATMENT-LB	TOTAL LOAD INTO KESWICK W/O TREATMENT-LB	% CONTRIBUTION INTO KESWICK W/ TREATMENT PLANT OPERATING			% CONTRIBUTION INTO KESWICK W/O TREATMENT PLANT OPERATING		
											SHASTA	SCPP	SCDD	SHASTA	SCPP	SCDD
1-Jun-96	293,167	1,761.6	0.049	1,761.5			13.9	189.1	203.0	203.0						
2-Jun-96	291,525	1,744.4	0.049	1,744.3			12.8	177.9	190.7	190.7						
3-Jun-96	291,254	1,742.8	0.049	1,742.7			12.6	207.3	219.9	219.9						
4-Jun-96	365,916	2,702.6	0.086	2,702.5	184.5	2,887.0	13.2	189.5	3,089.7	387.2	48.9%	3.4%	47.6%	6.1%	0.4%	93.4%
5-Jun-96	326,780	2,230.8	0.055	2,230.7	192.0	2,422.7	20.3	207.1	2,650.1	419.4	49.4%	4.8%	45.8%	7.8%	0.8%	91.4%
6-Jun-96	328,358	2,027.8	0.055	2,027.8			18.7	208.4	227.1	227.1						
7-Jun-96	313,200	1,957.7	0.052	1,957.7			28.6	203.0	231.6	231.6						
8-Jun-96	278,800	1,645.0	0.047	1,644.9			28.2	179.4	207.6	207.6						
9-Jun-96	277,200	1,596.2	0.083	1,596.1			28.4	199.5	227.9	227.9						
10-Jun-96	323,400	1,829.9	0.054	1,829.8			27.7	183.6	211.3	211.3						
11-Jun-96	307,700	1,784.7	0.051	1,784.6			27.8	175.9	203.7	203.7						
12-Jun-96	278,500	1,592.1	0.046	1,592.0	192.0	1,784.0	29.0	173.5	1,986.5	394.5	44.0%	7.4%	48.7%	8.7%	1.5%	89.8%
13-Jun-96	284,247	1,568.0	0.047	1,568.0			26.4	174.3	200.7	200.7						
14-Jun-96	272,638	1,506.2	0.046	1,506.2			26.5	185.0	211.5	211.5						
15-Jun-96	257,343	1,400.3	0.043	1,400.2			44.0	164.4	208.4	208.4						
16-Jun-96	253,178	1,542.4	0.042	1,542.4			40.5	168.2	208.7	208.7						
17-Jun-96	234,735	1,410.5	0.039	1,410.4			40.6	153.5	194.1	194.1						
18-Jun-96	258,183	1,467.3	0.095	1,467.2	230.9	1,698.1	40.4	169.1	1,907.6	440.4	38.4%	9.2%	52.4%	8.9%	2.1%	89.0%
19-Jun-96	256,716	1,439.7	0.043	1,439.7	227.6	1,667.3	40.3	140.2	1,847.8	408.1	34.4%	9.9%	55.8%	7.6%	2.2%	90.2%
20-Jun-96	257,787	1,467.2	0.043	1,467.2			40.6	157.7	198.3	198.3						
21-Jun-96	213,150	1,679.2	0.036	1,679.2			41.4	137.3	178.7	178.7						
22-Jun-96	149,085	1,493.0	0.025	1,493.0			41.0	154.3	195.3	195.3						
23-Jun-96	160,611	1,487.8	0.027	1,487.8			40.3	150.0	190.3	190.3						
24-Jun-96	189,559	1,401.6	0.032	1,401.6			41.7	148.2	189.9	189.9						
25-Jun-96	257,298	1,382.8	0.056	1,382.8			41.5	121.8	163.3	163.3						
26-Jun-96	255,217	1,365.3	0.043	1,365.2	173.7	1,538.9	47.6	131.7	1,718.2	353.0	37.3%	13.5%	49.2%	7.7%	2.8%	89.6%
27-Jun-96	215,458	1,506.8	0.036	1,506.8			45.8	139.2	185.0	185.0						
28-Jun-96	195,933	1,314.7	0.033	1,314.6			45.6	139.1	184.7	184.7						
29-Jun-96	257,748	1,348.7	0.043	1,348.6			47.3	140.0	187.3	187.3						
30-Jun-96	257,556	1,341.2	0.043	1,341.2			47.4	151.4	198.8	198.8						
										Minimum	34.4%	3.4%	45.8%	6.1%	0.4%	89.0%
										Average	42.1%	8.0%	49.9%	7.8%	1.6%	90.6%
										Maximum	49.4%	13.5%	55.8%	8.9%	2.8%	93.4%

For January 1995 and March 1995 Analyses:

Assumes Shasta zinc concentration = 3.6 µg/L

Assumes SCPP zinc concentration = 3.3 µg/L

For February 1996, June 1996, and December 1996-January 1997 Analyses:

Assumes Shasta zinc concentration = 2.7 µg/L

Assumes SCPP zinc concentration = 2.6 µg/L

ATTACHMENT 1

DISTRIBUTION OF LOADS INTO KESWICK RESERVOIR WITH IMM TREATMENT PLANT IN OPERATION (ACTUAL)
AND COMPUTED LOAD WITHOUT IMM TREATMENT PLANT OPERATING
ZINC LOADS

DATE	GALLONS TREATED	INFLUENT-LB	EFFLUENT-LB	LOAD REMOVED BY TREATMENT-LB	ACTUAL SCDD LOAD-LBS	TOTAL LOAD-LBS	ASSUMED SCPP LOAD-LBS	ASSUMED SHASTA LOAD-LBS	TOTAL LOAD INTO KESWICK W/TREATMENT-LB	TOTAL LOAD INTO KESWICK W/O TREATMENT-LB	% CONTRIBUTION INTO KESWICK W/ TREATMENT PLANT OPERATING			% CONTRIBUTION INTO KESWICK W/O TREATMENT PLANT OPERATING		
											SHASTA	SCPP	SCDD	SHASTA	SCPP	SCDD
25-Dec-96	299264	1,426.1	0.050	1,426.0			8.0	158.1	166.1	166.1						
26-Dec-96	302788	1,341.8	0.051	1,341.7	77.1	1,418.8	8.1	141.8	1,568.7	227.0	62.5%	3.6%	34.0%	9.0%	0.5%	90.4%
27-Dec-96	300371	1,258.4	0.050	1,258.3	71.7	1,330.0	8.0	256.2	1,594.2	335.9	76.3%	2.4%	21.3%	16.1%	0.5%	83.4%
28-Dec-96	312879	1,297.7	0.052	1,297.7			13.4	351.9	365.3	365.3						
29-Dec-96	348681	1,289.1	0.058	1,289.0	932.1	2,221.1	36.7	530.5	2,788.3	1,499.3	35.4%	2.4%	62.2%	19.0%	1.3%	79.7%
30-Dec-96	488269	1,955.9	0.081	1,955.8	908.9	2,864.7	53.7	591.4	3,509.8	1,554.0	38.1%	3.5%	58.5%	16.8%	1.5%	81.6%
31-Dec-96	1559571	7,744.1	0.260	7,743.9	722.8	8,466.7	52.5	305.4	8,824.6	1,080.7	28.3%	4.9%	66.9%	3.5%	0.6%	95.9%
1-Jan-97	2036700	11,643.1	0.374	11,642.7	3,293.5	14,936.2	49.3	118.7	15,104.2	3,461.5	3.4%	1.4%	95.1%	0.8%	0.3%	98.9%
2-Jan-97	2530300	14,443.7	2.365	14,441.3	5,391.7	19,833.0	4.1	627.1	20,464.2	6,022.9	10.4%	0.1%	89.5%	3.1%	0.0%	96.9%
3-Jan-97	2146000	16,763.2	0.519	16,762.6	2,457.3	19,219.9	26.7	943.4	20,190.0	3,427.4	27.5%	0.8%	71.7%	4.7%	0.1%	95.2%
4-Jan-97	1497500	11,410.1	0.337	11,409.7	1,731.8	13,141.5	55.5	1,079.1	14,276.1	2,866.4	37.6%	1.9%	60.4%	7.6%	0.4%	92.1%
5-Jan-97	1239500	9,175.3	0.755	9,174.5	1,541.1	10,715.6	51.8	912.3	11,679.7	2,505.2	36.4%	2.1%	61.5%	7.8%	0.4%	91.7%
6-Jan-97	1083500	7,893.9	0.335	7,893.6	1,278.8	9,172.4	51.9	640.0	9,864.3	1,970.7	32.5%	2.6%	64.9%	6.5%	0.5%	93.0%
7-Jan-97	995500	6,621.4	0.166	6,621.2	994.4	7,615.6	52.4	673.5	8,341.5	1,720.3	39.2%	3.0%	57.8%	8.1%	0.6%	91.3%
8-Jan-97	954000	5,971.2	0.247	5,970.9	901.4	6,872.3	34.8	708.8	7,615.9	1,645.0	43.1%	2.1%	54.8%	9.3%	0.5%	90.2%
										Minimum	3.4%	0.1%	21.3%	0.8%	0.0%	79.7%
										Average	36.2%	2.4%	61.4%	8.6%	0.6%	90.8%
										Maximum	76.3%	4.9%	95.1%	19.0%	1.5%	98.9%

For January 1995 and March 1995 Analyses:

Assumes Shasta zinc concentration = 3.6 μg/L

Assumes SCPP zinc concentration = 3.3 μg/L

For February 1996, June 1996, and December 1996-January 1997 Analyses:

Assumes Shasta zinc concentration = 2.7 μg/L

Assumes SCPP zinc concentration = 2.6 μg/L

ATTACHMENT 2

MORRISON KNUDSEN SPREADSHEETS

Table 4. Keswick Reservoir Precipitation

Shasta System
Copper (Dissolved) Mass Balance
Page 1 of 2 (January 1995)

Date	Shasta Dam Output [lbs/day]	Percent of Keswick Input	SCDD Outlet [lbs/day]	SCDD Spillway [lbs/day]	SCDD Total Output [lbs/day]	Percent of Keswick Input	SCPP Flow [cfs]	Whiskeytown SCPP Output [lbs/day]	Percent of Keswick Input	Calculated Keswick Input [lbs/day]	Keswick Output [lbs/day]	Percent Precipitation
01/03/95	38	23.6%	122	0	122	75.2%	302	2	1.2%	162	82	49.4%
01/06/95	34	21.7%	119	0	119	77.1%	272	2	1.1%	154	NA	NA
01/09/95	3	0.4%	789	0	789	97.5%	2716	18	2.2%	809	NA	NA
01/10/95	20	1.9%	977	0	977	95.3%	4322	28	2.7%	1025	181	82.4%
01/11/95	35	2.5%	1364	0	1364	95.5%	4404	29	2.0%	1428	356	75.1%
01/12/95	21	0.7%	1830	1271	3101	98.4%	4387	28	0.9%	3150	431	86.3%
01/13/95	35	0.8%	2835	1521	4356	98.5%	4737	31	0.7%	4421	318	92.8%
01/14/95	38	1.3%	65	2727	2792	97.7%	4383	28	1.0%	2858	400	86.0%
01/15/95	94	7.1%	592	617	1209	90.8%	4447	29	2.2%	1332	399	70.0%
01/16/95	104	5.9%	1643	0	1643	92.6%	4229	27	1.5%	1774	462	74.0%
01/17/95	130	7.2%	1663	0	1663	91.3%	4281	28	1.5%	1821	539	70.4%
01/18/95	197	10.1%	1732	0	1732	88.5%	4281	28	1.4%	1956	741	62.1%
01/19/95	334	14.0%	2020	0	2020	84.8%	4201	27	1.1%	2381	NA	NA
01/20/95	335	23.7%	1051	0	1051	74.3%	4300	28	2.0%	1414	NA	NA
01/23/95	102	16.1%	503	0	503	79.5%	4301	28	4.4%	633	472	25.3%
01/25/95	82	23.4%	242	0	242	68.7%	4273	28	7.9%	352	322	8.5%
01/27/95	148	31.0%	302	0	302	63.3%	4243	27	5.8%	477	387	19.0%
01/30/95	241	23.4%	769	0	769	74.9%	2567	17	1.6%	1026	NA	NA
01/31/95	172	11.6%	1285	0	1285	86.7%	3945	26	1.7%	1483	699	52.8%
	2163	7.5%	19903	6136	26039	90.9%	70591	457	1.6%	28659	5790	

Notes:
1. na = not available
2. SCPP copper and zinc concentrations are assumed to be 1.2 and 3.3 ug/l respectively

Table 4. Keswick Reservoir Precipitation

IRON MOUNTAIN MINE OFF-SITE
METALS LOADING DURING 1995 STORMS
MORRISON KNUDSEN CORPORATION
SEPTEMBER 1995

Shasta System
Copper (Dissolved) Mass Balance
Page 2 of 2 (March 1995)

Date	Shasta Dam Output [lbs/day]	Percent of Keswick Input	SCDD Outlet [lbs/day]	SCDD Spillway [lbs/day]	SCDD Total Output [lbs/day]	Percent of Keswick Input	SCPP Flow [cfs]	Whiskeytown SCPP Output [lbs/day]	Percent of Keswick Input	Calculated Keswick Input	Keswick Output [lbs/day]	Percent Precipitation
03/01/95	50	31.6%	107	0	107	67.4%	252	2	1.0%	158	55	65.3%
03/02/95	47	31.2%	101	0	101	67.7%	254	2	1.1%	149	56	62.6%
03/03/95	45	32.5%	88	0	88	63.4%	868	6	4.1%	138	110	20.7%
03/04/95	17	NA	NA	0	NA	NA	2183	14	NA	NA	NA	NA
03/05/95	44	NA	NA	0	NA	NA	251	2	NA	NA	NA	NA
03/06/95	46	39.3%	70	0	70	59.3%	252	2	1.4%	118	81	30.9%
03/07/95	51	26.8%	137	0	137	72.3%	248	2	0.9%	189	54	71.2%
03/08/95	48	22.9%	160	0	160	76.3%	252	2	0.8%	210	72	65.6%
03/09/95	24	15.4%	124	0	124	78.2%	1572	10	6.4%	158	160	-1.2%
03/10/95	95	24.1%	272	0	272	69.2%	4083	26	6.7%	393	326	17.0%
03/11/95	442	36.3%	748	0	748	61.5%	4069	26	2.2%	1216	932	23.4%
03/12/95	544	32.5%	1104	0	1104	66.0%	4047	26	1.6%	1674	648	61.3%
03/13/95	547	29.7%	1266	0	1266	68.8%	4235	27	1.5%	1841	1493	18.9%
03/14/95	480	29.0%	1150	0	1150	69.4%	4200	27	1.6%	1658	1052	36.6%
03/15/95	610	30.6%	1367	0	1367	68.6%	2477	16	0.8%	1993	942	52.7%
03/16/95	731	32.6%	1508	0	1508	67.3%	210	1	0.1%	2240	814	63.6%
03/17/95	736	30.5%	1661	0	1661	68.9%	2197	14	0.6%	2411	1918	20.4%
03/18/95	723	NA	NA	0	NA	NA	4123	27	NA	NA	NA	NA
03/19/95	674	NA	NA	0	NA	NA	4137	27	NA	NA	NA	NA
03/20/95	469	30.5%	1042	0	1042	67.7%	4160	27	1.8%	1538	979	36.4%
03/21/95	485	31.9%	1009	0	1009	66.3%	4170	27	1.8%	1520	812	46.6%
03/22/95	473	56.1%	347	0	347	41.1%	3573	23	2.7%	843	951	-12.8%
03/23/95	475	54.0%	378	0	378	43.0%	4185	27	3.1%	880	539	38.7%
03/24/95	473	51.7%	414	0	414	45.3%	4184	27	3.0%	914	803	12.2%
03/25/95	379	NA	NA	0	NA	NA	4225	27	NA	NA	NA	NA
03/26/95	329	NA	NA	0	NA	NA	1931	13	NA	NA	NA	NA
03/27/95	361	43 9%	457	0	457	55 6%	686	4	0.5%	822	654	20.5%
03/28/95	290	45.8%	337	0	337	53.2%	1017	7	1.0%	634	455	28.2%
03/29/95	256	42.4%	341	0	341	56.6%	916	6	1.0%	602	NA	NA
03/30/95	212	37.1%	353	0	353	61.6%	1153	7	1.3%	573	222	61.2%
03/31/95	180	40.1%	264	0	264	58.8%	723	5	1.0%	449	184	59.0%
	10335	44.3%	14803	0	14803	63.5%	70833	459	2.0%	23322	14314	

Notes:
1 na = not available
2. SCPP copper and zinc concentrations are assumed to be 1.2 and 3.3 ug/l respectively

Table 5. Keswick Reservoir Precipitation

Shasta System
Zinc (Dissolved) Mass Balance
Page 1 of 2 (January 1995)

Date	Shasta Dam Output [lbs/day]	Percent of Keswick Input	SCDD Outlet [lbs/day]	SCDD Spillway [lbs/day]	SCDD Total Outpu [lbs/day]	Percent of Keswick Input	SCPP Flow [cfs]	Whiskeytown SCPP Output [3] [lbs/day]	Percent of Keswick Input	Calculated Keswick Input [lbs/day]	Keswick Output [lbs/day]	Percent Precipitation
01/03/95	69	22.3%	235	0	235	75.9%	302	5	1.7%	309	308	0.3%
01/06/95	60	20.4%	230	0	230	78.0%	272	5	1.6%	295	326	-10.6%
01/09/95	5	0.3%	1659	0	1659	96.9%	2716	48	2.8%	1712	172	90.0%
01/10/95	36	1.8%	1854	0	1854	94.3%	4322	77	3.9%	1967	271	86.2%
01/11/95	64	2.2%	2790	0	2790	95.1%	4404	78	2.7%	2932	1881	35.9%
01/12/95	37	0.6%	3985	2029	6014	98.1%	4387	78	1.3%	6129	1510	75.4%
01/13/95	62	0.6%	6827	2604	9431	98.5%	4737	84	0.9%	9577	1235	87.1%
01/14/95	68	1.5%	194	4280	4474	96.8%	4383	78	1.7%	4620	1971	57.3%
01/15/95	169	7.4%	1129	922	2051	89.2%	4447	79	3.4%	2299	1428	37.9%
01/16/95	187	5.6%	3089	0	3089	92.2%	4229	75	2.2%	3351	1981	40.9%
01/17/95	235	7.6%	2771	0	2771	89.9%	4281	76	2.5%	3082	2335	24.2%
01/18/95	354	11.1%	2769	0	2769	86.6%	4281	76	2.4%	3199	2469	22.8%
01/19/95	602	15.3%	3252	0	3252	82.8%	4201	75	1.9%	3929	2230	43.2%
01/20/95	604	25.4%	1700	0	1700	71.4%	4300	77	3.2%	2381	1642	31.0%
01/23/95	183	16.7%	834	0	834	76.3%	4301	77	7.0%	1094	866	20.8%
01/25/95	148	24.3%	386	0	386	63.3%	4273	76	12.5%	610	580	5.0%
01/27/95	266	32.9%	466	0	466	57.7%	4243	76	9.4%	808	677	16.2%
01/30/95	433	28.2%	1057	0	1057	68.8%	2567	46	3.0%	1536	701	54.3%
01/31/95	310	15.0%	1685	0	1685	81.6%	3945	70	3.4%	2065	1515	26.6%
	3892	7.5%	36912	9835	46747	90.1%	70591	1257	2.4%	51895	24098	

Notes:
1. na = not available
2. SCPP copper and zinc concentrations are assumed to be 1.2 and 3.3 ug/l respectively

IRON MOUNTAIN MINE OFF-SITE
METALS LOADING DURING 1995 STORMS
MORRISON KNUDSEN CORPORATION
SEPTEMBER 1995

Table 5. Keswick Reservoir Precipitation - March 1995

IRON MOUNTAIN MINE OFF-SITE
METALS LOADING DURING 1995 STORMS
MORRISON KNUDSEN CORPORATION
SEPTEMBER 1995

Shasta System
Zinc (Dissolved) Mass Balance

Date	Shasta Dam Output [lbs/day]	Percent of Keswick Input	SCDD Outlet [lbs/day]	SCDD Spillway [lbs/day]	SCDD Total Output [lbs/day]	Percent of Keswick Input	SCPP Flow [cfs]	Whiskeytown SCPP Output [2] [lbs/day]	Percent of Keswick Input	Calculated Keswick Input [lbs/day]	Keswick Output [lbs/day]	Percent Precipitation
03/01/95	90	35.7%	157	0	157	62.5%	252	4	1.8%	252	329	-30.8%
03/02/95	84	35.4%	148	0	148	62.7%	254	5	1.9%	236	56	76.5%
03/03/95	81	33.8%	143	0	143	59.7%	868	15	6.5%	239	192	19.8%
03/04/95	30	NA	NA	0	NA	NA	2183	39	NA	NA	NA	NA
03/05/95	79	NA	NA	0	NA	NA	251	4	NA	NA	NA	NA
03/06/95	83	41.7%	112	0	112	56.1%	252	4	2.2%	200	95	52.5%
03/07/95	91	29.2%	217	0	217	69.4%	248	4	1.4%	313	NA	NA
03/08/95	87	24.4%	264	0	264	74.4%	252	4	1.3%	355	136	61.8%
03/09/95	44	13.7%	248	0	248	77.6%	1572	28	8.7%	320	200	37.5%
03/10/95	170	22.3%	521	0	521	68.2%	4083	73	9.5%	764	465	39.1%
03/11/95	796	37.9%	1233	0	1233	58.7%	4069	72	3.4%	2101	533	74.7%
03/12/95	978	40.2%	1385	0	1385	56.9%	4047	72	3.0%	2435	NA	NA
03/13/95	985	38.0%	1536	0	1536	59.1%	4235	75	2.9%	2597	996	61.7%
03/14/95	865	37.7%	1353	0	1353	59.0%	4200	75	3.3%	2293	1052	54.1%
03/15/95	1097	42.6%	1434	0	1434	55.7%	2477	44	1.7%	2575	1240	51.9%
03/16/95	1316	44.9%	1609	0	1609	54.9%	210	4	0.1%	2929	814	72.2%
03/17/95	1325	44.3%	1628	0	1628	54.4%	2197	39	1.3%	2992	NA	NA
03/18/95	1301	NA	NA	0	NA	NA	4123	73	NA	NA	NA	NA
03/19/95	1214	NA	NA	0	NA	NA	4137	74	NA	NA	NA	NA
03/20/95	845	36.9%	1369	0	1369	59.8%	4160	74	3.2%	2287	839	63.3%
03/21/95	872	37.1%	1407	0	1407	59.8%	4170	74	3.2%	2353	677	71.2%
03/22/95	852	63.6%	425	0	425	31.7%	3573	64	4.7%	1340	1359	-1.4%
03/23/95	855	64.0%	406	0	406	30.4%	4185	75	5.6%	1335	NA	NA
03/24/95	851	63.6%	413	0	413	30.9%	4184	74	5.6%	1339	535	60.0%
03/25/95	682	NA	NA	0	NA	NA	4225	75	NA	NA	NA	NA
03/26/95	592	NA	NA	0	NA	NA	1931	34	NA	NA	NA	NA
03/27/95	649	58.6%	447	0	447	40.3%	686	12	1.1%	1108	467	57.9%
03/28/95	523	59.5%	337	0	337	38.4%	1017	18	2.1%	878	304	65.4%
03/29/95	460	55.9%	347	0	347	42.1%	916	16	2.0%	824	NA	NA
03/30/95	382	50.2%	359	0	359	47.1%	1153	21	2.7%	761	NA	NA
03/31/95	325	53.0%	275	0	275	44.9%	723	13	2.1%	612	184	69.9%
	18603	55.6%	17773	0	17773	53.2%	70833	1261	3.8%	33439	10472	

Notes:
1 na = not available
2 SCPP copper and zinc concentrations are assumed to be 1.2 and 3.3 ug/l respectively

TABLE 5 (page 1 of 2)
Iron Mountain Mine
Shasta - Keswick - SCDD Reservoirs
Copper Loading
December 1996 - January 1997

Date	Copper Concentration (ug/l)																		Copper Load (lbs/day)				Total Load Into Keswick (lbs/day)	% Contribution Into Keswick		
	Shasta	SCDD						SCPP	Keswick Release										Shasta	SCDD	SCPP	Keswick Release		Shasta	SCDD	SCPP
	Assumed Conc.	SMC (Station LSC-15) 1	2	3	4	USBR 1	Avg	Assumed Conc.	SMC (Station SRK-16) 1	2	3	4	USBR 1	2	3	4	Avg									
12/25/96	1.2							1.0											70.3		3.1					
12/26/96	1.2	944					944	1.0	2.0								2.0		63.0	50.9	3.1	109.8	117.0	53.8%	43.5%	2.7%
12/27/96	1.2	887					887	1.0											113.9	47.8	3.1		164.8	69.1%	29.0%	1.9%
12/28/96	1.2							1.0											156.4		5.2					
12/29/96	1.2	351	249	321	289		303	1.0	4.0	2.0							3.0		235.8	652.7	14.1	642.1	902.6	26.1%	72.3%	1.6%
12/30/96	1.2	219	239	253	256	230	239	1.0	2.0	2.0			2.4				2.1		262.8	645.6	20.6	543.5	929.1	28.3%	69.5%	2.2%
12/31/96	1.2	200	214				207	1.0	3.0	3.0							3.0		135.7	558.3	20.2	484.8	714.2	19.0%	78.2%	2.8%
01/01/97	1.2	228	500	591	484		451	1.0	< 2	3.0			<5	1.9			2.5		52.8	1449.0	19.0	218.3	1520.8	3.5%	95.3%	1.2%
01/02/97	1.2	581	546	545	646	210	506	1.0	6.0	6.0	7.0	4.0	<5	3.7	5.0		5.3		278.7	2318.1	1.6	1205.3	2598.3	10.7%	89.2%	0.1%
01/03/97	1.2	457	412	402		470	435	1.0	3.0	4.0	3.0		<5	3.0			3.3		419.3	1373.4	10.3	1186.2	1802.9	23.3%	76.2%	0.6%
01/04/97	1.2	378				380	379	1.0	6.0				<5	4.5			5.2		479.6	991.5	21.4	2210.8	1492.4	32.1%	66.4%	1.4%
01/05/97	1.2	431					431	1.0											405.5	890.4	19.9		1315.8	30.8%	67.7%	1.5%
01/06/97	1.2	369					369	1.0					1.0				1.0		284.4	762.3	20.0	271.8	1066.7	26.7%	71.5%	1.9%
01/07/97	1.2	380				380	380	1.0					<5	1.6			1.6		299.3	547.3	20.1	431.9	866.7	34.5%	63.1%	2.3%
01/08/97	1.2	360				380	370	1.0	2.0				<5	1.5			1.8		315.0	498.9	13.4	497.7	827.4	38.1%	60.3%	1.6%
																							Minimum	3.5%	29.0%	0.1%
																							Maximum	69.1%	95.3%	2.8%

Notes:
1) Assumed copper concentrations:
Shasta = 1.2 ug/l
SCPP = 1.0 ug/l
2) Keswick sample results below the detection limit are not included in the loading calculation, "<" indicates result less than indicated detection limit.
3) Total load into Keswick equals sum of Shasta, SCDD and SCPP loads
4) Blank indicates data are not available.
5) Ref 1,2,3,7, and 8.

CIV-S-91-768 DFL JFM

DECLARATION OF
ANNE C. CONNELL

Date: August 29, 1997
Time: 9:00 a.m.
Judge: Hon. David F. Levi
Place: Courtroom No. 3

TABLE 6 (page 1 of 2)
Iron Mountain Mine
Shasta - Keswick - SCDD Reservoirs
Copper Loading
February 1996

Date	Copper Concentration (ug/l)												Copper Load (lbs/day)				Total Load	% Contribution into Keswick		
	Shasta	SCDD						SCPP	Keswick Release				Shasta	SCDD	SCPP	Keswick	Into Keswick	Shasta	SCDD	SCPP
	Assumed	SMC (Station LSC-15)				USBR	Avg	Assumed	SMC (SRK-16)		USBR	Avg				Release	(lbs/day)			
	Conc.	1	2	3	4	1		Conc.	1	2	1									
02/01/96	1.2	507					507	1.0					42.1	194.2	9.8		246.0	17.1%	78.9%	4.0%
02/02/96	1.2	525					525	1.0					34.4	147.3	9.8		191.4	18.0%	76.9%	5.1%
02/03/96	1.2	624					624	1.0					36.9	134.6	2.0		173.4	21.2%	77.6%	1.1%
02/04/96	1.2	620					620	1.0					25.4	133.8	6.1		165.3	15.4%	80.9%	3.7%
02/05/96	1.2	595	597				596	1.0	4.0	3.0		3.5	19.9	157.5	9.6	135.1	187.0	10.6%	84.2%	5.1%
02/06/96	1.2	599					599	1.0					46.2	323.1	10.0		379.3	12.2%	85.2%	2.6%
02/07/96	1.2	574				580	577	1.0	6.0			6.0	53.7	373.5	10.2	324.4	437.4	12.3%	85.4%	2.3%
02/08/96	1.2	532					532	1.0					58.5	344.3	10.3		413.2	14.2%	83.3%	2.5%
02/09/96	1.2	489					489	1.0					48.0	316.5	11.8		376.3	12.8%	84.1%	3.1%
02/10/96	1.2	547					547	1.0					101.3	354.1	12.3		467.6	21.7%	75.7%	2.6%
02/11/96	1.2	504					504	1.0					110.7	326.2	19.7		456.6	24.2%	71.4%	4.3%
02/12/96	1.2	590					590	1.0					123.0	334.1	19.7		476.9	25.8%	70.1%	4.1%
02/13/96	1.2	535				540	538	1.0					178.3	231.9	19.7		430.0	41.5%	53.9%	4.6%
02/14/96	1.2	613					613	1.0	<2				195.8	264.5	20.1		480.4	40.7%	55.1%	4.2%
02/15/96	1.2	625					625	1.0					190.9	168.6	21.3		380.7	50.1%	44.3%	5.6%
02/16/96	1.2	571					571	1.0					154.4	154.0	21.3		329.7	46.8%	46.7%	6.5%
02/17/96	1.2	544					544	1.0					157.1	146.7	21.3		325.1	48.3%	45.1%	6.5%
02/18/96	1.2	41	48	59			49	1.0					175.4	38.1	21.4		234.9	74.7%	16.2%	9.1%
02/19/96	1.2	182	131	183	184		170	1.0					200.9	131.1	21.6		353.7	56.8%	37.1%	6.1%
02/20/96	1.2	230	229	259	246	250	243	1.0					194.6	392.9	21.4		608.9	32.0%	64.5%	3.5%
02/21/96	1.2	232					232	1.0	2.0			2.0	213.0	375.4	20.9	412.6	609.3	35.0%	61.6%	3.4%
02/22/96	1.2	297					297	1.0					89.7	480.6	6.3		576.6	15.6%	83.3%	1.1%
02/23/96	1.2	286					286	1.0					320.5	231.4	6.3		558.3	57.4%	41.4%	1.1%
02/24/96	1.2	328					328	1.0					336.5	265.4	9.2		611.1	55.1%	43.4%	1.5%
02/25/96	1.2	366					366	1.0					324.8	252.7	8.9		586.4	55.4%	43.1%	1.5%
02/26/96	1.2	265					265	1.0					336.7	107.2	9.0		452.9	74.3%	23.7%	2.0%
02/27/96	1.2	247				280	264	1.0					296.2	106.6	14.2		417.0	71.0%	25.6%	3.4%
02/28/96	1.2	340					340	1.0	<2				270.6	137.5	21.1		429.3	63.0%	32.0%	4.9%
02/29/96	1.2	110					110	1.0	<2				211.4	78.9	21.3		311.6	67.9%	25.3%	6.8%
																	Minimum	10.6%	16.2%	1.1%
																	Maximum	74.7%	85.4%	9.1%

1) Assumed copper concentrations:
Shasta = 1.2 ug/l
SCPP = 1.0 ug/l
2) Keswick sample results below the detection limit are not included in the loading calculation; "<" indicates result less than indicated detection limit.
3) Total load into Keswick equals sum of Shasta, SCDD and SCPP loads
4) Blank indicates data are not available
5) Ref 1, 7 and 8.

CIV-S-91-768 DFL JFM

DECLARATION OF
ANNE C. CONNELL

Date: August 29, 1997
Time: 9:00 a.m.
Judge: Hon. David F. Levi
Place: Courtroom No. 3

TABLE 7 (page 1 of 2)
Iron Mountain Mine
Shasta - Keswick - SCDD Reservoirs
Copper Loading
June 1996

Date	Copper Concentration (ug/l)								Copper Load (lbs/day)				Total Load	% Contribution into Keswick		
	Shasta	SCDD			SCPP	Keswick Release			Shasta	SCDD	SCPP	Keswick Release	Into Keswick (lbs/day)	Shasta	SCDD	SCPP
	Assumed Conc.	SMC LSC-15	USBR	Avg	Assumed Conc.	SMC SRK-16	USBR	Avg								
06/01/96	1.2				1.0				84.1		5.4					
06/02/96	1.2				1.0				79.1		4.9					
06/03/96	1.2				1.0				92.2		4.9					
06/04/96	1.2		830	830	1.0				84.2	89.5	5.1		178.9	47.1%	50.1%	2.8%
06/05/96	1.2	834		834	1.0	3.0		3.0	92.1	90.0	7.9	242.7	190.0	48.5%	47.4%	4.2%
06/06/96	1.2				1.0				92.6		7.2					
06/07/96	1.2				1.0				90.2		11.0					
06/08/96	1.2				1.0				79.8		10.8					
06/09/96	1.2				1.0				88.7		10.9					
06/10/96	1.2				1.0				81.6		10.7					
06/11/96	1.2				1.0				78.2		10.7					
06/12/96	1.2	1030	1080	1055	1.0	<2			77.1	113.8	11.1		202.1	38.2%	56.3%	5.5%
06/13/96	1.2				1.0				77.4		10.1					
06/14/96	1.2				1.0				82.2		10.2					
06/15/96	1.2				1.0				73.1		16.9					
06/16/96	1.2				1.0				74.7		15.6					
06/17/96	1.2				1.0				68.2		15.6					
06/18/96	1.2		1120	1120	1.0				75.2	120.8	15.5		211.5	35.5%	57.1%	7.3%
06/19/96	1.2	1030		1030	1.0	<2			62.3	111.1	15.5		188.9	33.0%	58.8%	8.2%
06/20/96	1.2				1.0				70.1		15.6					
06/21/96	1.2				1.0				61.0		15.9					
06/22/96	1.2				1.0				68.6		15.8					
06/23/96	1.2				1.0				66.7		15.5					
06/24/96	1.2				1.0				65.9		16.0					
06/25/96	1.2				1.0				54.1		15.9					
06/26/96	1.2	1290	1170	1230	1.0	<2			58.5	92.9	18.3		169.7	34.5%	54.7%	10.8%
06/27/96	1.2				1.0				61.9		17.6					
06/28/96	1.2				1.0				61.8		17.5					
06/29/96	1.2				1.0				62.2		18.2					
06/30/96	1.2				1.0				67.3		18.2					
													Minimum	33.0%	47.4%	2.8%
													Maximum	48.5%	58.8%	10.8%

Notes:
1) Assumed copper concentrations:
Shasta = 1.2 ug/l
SCPP = 1.0 ug/l
2) Keswick sample results below the detection limit are not included in the loading calculation; "<" indicates result less than indicated detection limit.
3) Total load into Keswick equals sum of Shasta, SCDD and SCPP loads
4) Blank indicates data are not available
5) Ref. 1, 7, and 8

CIV-S-91-768 DFL JFM

DECLARATION OF
ANNE C. CONNELL

TABLE 8 (page [illegible] 2)
Iron Mountain Mine
Shasta - Keswick - SCDD Reservoirs
Zinc Loading
December 1996 - January 1997

Date	Zinc Concentration (ug/l)																	Zinc Load (lbs/day)				Total Load Into Keswick (lbs/day)	% Contribution Into Keswick		
		SCDD						SCPP	Keswick Release									Shasta	SCDD	SCPP	Keswick Release		Shasta	SCDD	SCPP
	Assumed Conc.	SMC (Station LSC-15)				USBR	Avg	Assumed Conc.	SMC (Station SRK-16)				USBR				Avg								
		1	2	3	4	1			1	2	3	4	1	2	3										
12/25/96	2.7							2.6										158.1		8.0					
12/26/96	2.7	1430					1430	2.6	16.0								16.0	141.8	77.1	8.1	878.0	227.0	62.4%	34.0%	3.6%
12/27/96	2.7	1330					1330	2.6										256.2	71.7	8.0		335.9	76.3%	21.4%	2.4%
12/28/96	2.7							2.6										351.9		13.4					
12/29/96	2.7	489	377	445	417		432	2.6	<10	<10								530.5	932.1	36.7		1499.3	35.4%	62.2%	2.4%
12/30/96	2.7	307	341	360	357	320	337	2.6	<10	<10			6.5				6.5	591.4	908.9	53.7	1682.2	1553.9	38.1%	58.5%	3.5%
12/31/96	2.7	265	271				268	2.6	<10	<10								305.4	722.8	52.5		1080.6	28.3%	66.9%	4.9%
01/01/97	2.7	478	1120	1380	1120		1025	2.6	<10	<10			4.4				4.4	118.7	3293.5	49.3	392.1	3461.5	3.4%	95.1%	1.4%
01/02/97	2.7	1380	1310	1270	1530	390	1176	2.6	11.0	12.0	18.0	<10	12.5				13.4	627.1	5391.7	4.1	3047.4	6022.9	10.4%	89.5%	0.1%
01/03/97	2.7	815	726	664		910	779	2.6	<10	<10	<10		10.8				10.8	943.4	2457.3	26.7	3882.2	3427.4	27.5%	71.7%	0.8%
01/04/97	2.7	654				670	662	2.6	<10				8.7				8.7	1079.1	1731.8	55.5	3698.8	2866.4	37.6%	60.4%	1.9%
01/05/97	2.7	746					746	2.6										912.3	1541.1	51.8		2505.2	36.4%	61.5%	2.1%
01/06/97	2.7	619					619	2.6					5.0				5.0	640.0	1278.8	51.9	1359.2	1970.7	32.5%	64.9%	2.6%
01/07/97	2.7	681				700	691	2.6					4.8				4.8	673.5	994.4	52.4	1295.6	1720.3	39.2%	57.8%	3.0%
01/08/97	2.7	667				670	669	2.6	<10				5.2				5.2	708.8	901.4	34.8	1414.1	1645.1	43.1%	54.8%	2.1%
																						Minimum	3.4%	21.4%	0.1%
																						Maximum	76.3%	95.1%	4.9%

1) Assumed zinc concentrations:
Shasta = 2.7 ug/l
SCPP = 2.6 ug/l
2) Keswick sample results below the detection limit are not included in the loading calculation; "<" indicates result less than indicated detection limit.
3) Total load into Keswick equals sum of Shasta, SCDD and SCPP loads
4) Blank indicates data are not available
5) Ref 1,2,3,7 and 8.

CIV-S-91-768 DFL JFM

DECLARATION OF
ANNE C. CONNELL

Date: August 29, 1997
Time: 9:00 a.m.
Judge: Hon. David F. Levi
Place: Courtroom No. 3

TABLE 9 (page 1 of 2)
Iron Mountain Mine
Shasta - Keswick - SCDD Reservoirs
Zinc Loading
February 1996

Date	Zinc Concentration (ug/l)													Zinc Load (lbs/day)				Total Load	% Contribution into Keswick		
	Shasta	SCDD						SCPP	Keswick Release				Shasta	SCDD	SCPP	Keswick	Into Keswick	Shasta	SCDD	SCPP
	Assumed	SMC (Station LSC-15)				USBR	Avg	Assumed	SMC (SRK-16)		USBR	Avg				Release	(lbs/day)			
	Conc.	1	2	3	4	1		Conc.	1	2	1									
02/01/96	2.7	753					753	2.6					94.7	288.4	25.4		408.5	23.2%	70.6%	6.2%
02/02/96	2.7	761					761	2.6					77.3	213.4	25.5		316.2	24.4%	67.5%	8.0%
02/03/96	2.7	871					871	2.6					82.9	187.9	5.1		275.9	30.1%	68.1%	1.8%
02/04/96	2.7	911					911	2.6					57.2	196.6	15.9		269.7	21.2%	72.9%	5.9%
02/05/96	2.7	851	844				848	2.6	9.0	7.0		8.0	44.8	224.0	25.0	308.7	293.8	15.2%	76.2%	8.5%
02/06/96	2.7	831					831	2.6					104.0	448.2	26.0		578.2	18.0%	77.5%	4.5%
02/07/96	2.7	789				840	815	2.6	15.0			15.0	120.8	527.2	26.6	811.1	674.6	17.9%	78.1%	3.9%
02/08/96	2.7	691					691	2.6					131.6	447.3	26.9		605.7	21.7%	73.8%	4.4%
02/09/96	2.7	623					623	2.6					108.0	403.2	30.6		541.9	19.9%	74.4%	5.6%
02/10/96	2.7	715					715	2.6					227.9	462.8	31.9		722.7	31.5%	64.0%	4.4%
02/11/96	2.7	698					698	2.6					249.0	451.8	51.3		752.1	33.1%	60.1%	6.8%
02/12/96	2.7	837					837	2.6					276.8	474.0	51.2		802.1	34.5%	59.1%	6.4%
02/13/96	2.7	707				700	704	2.6					401.3	303.6	51.2		756.0	53.1%	40.2%	6.8%
02/14/96	2.7	824					824	2.6	6.0			6.0	440.4	355.6	52.4	1143.6	848.4	51.9%	41.9%	6.2%
02/15/96	2.7	911					911	2.6					429.5	245.7	55.3		730.5	58.8%	33.6%	7.6%
02/16/96	2.7	987					987	2.6					347.4	266.2	55.3		669.0	51.9%	39.8%	8.3%
02/17/96	2.7	1220					1220	2.6					353.6	329.0	55.3		737.9	47.9%	44.6%	7.5%
02/18/96	2.7	193	206	217			205	2.6					394.7	158.4	55.6		608.7	64.8%	26.0%	9.1%
02/19/96	2.7	337	282	303	308		308	2.6					452.1	237.2	56.2		745.5	60.6%	31.8%	7.5%
02/20/96	2.7	346	345	354	342	330	343	2.6					437.9	555.7	55.5		1049.1	41.7%	53.0%	5.3%
02/21/96	2.7	329					329	2.6	7.0			7.0	479.2	532.4	54.4	1444.1	1066.0	45.0%	49.9%	5.1%
02/22/96	2.7	391					391	2.6					201.8	632.7	16.4		851.0	23.7%	74.4%	1.9%
02/23/96	2.7	406					406	2.6					721.2	328.5	16.5		1066.2	67.6%	30.8%	1.5%
02/24/96	2.7	470					470	2.6					757.2	380.3	23.9		1161.4	65.2%	32.7%	2.1%
02/25/96	2.7	582					582	2.6					730.8	401.8	23.2		1155.9	63.2%	34.8%	2.0%
02/26/96	2.7	779					779	2.6					757.6	315.1	23.4		1096.1	69.1%	28.8%	2.1%
02/27/96	2.7	1050				960	1005	2.6					666.5	406.6	36.9		1110.0	60.0%	36.6%	3.3%
02/28/96	2.7	1030					1030	2.6	<2				608.8	416.7	55.0		1080.5	56.3%	38.6%	5.1%
02/29/96	2.7	318					318	2.6	<2				475.7	228.1	55.3		759.1	62.7%	30.1%	7.3%
																	Minimum	15.2%	26.0%	1.5%
																	Maximum	69.1%	78.1%	9.1%

1) Assumed zinc concentrations:
Shasta = 2.7 ug/l
SCPP = 2.6 ug/l
2) Keswick sample results below the detection limit are not included in the loading calculation; "<" indicates result less than indicated detection limit.
3) Total load into Keswick equals sum of Shasta, SCDD and SCPP loads
4) Blank indicates data are not available
5) Ref 1, 7 and 8.

CIV-S-91-768 DFL JFM

DECLARATION OF
ANNE C. CONNELL

Date: August 29, 1997
Time: 9:00 a.m.
Judge: Hon. David F. Levi
Place: Courtroom No. 3

TABLE 10 (page 1 of 2)
Iron Mountain Mine
Shasta - Keswick - SCDD Reservoirs
Zinc Loading
June 1996

Date	Zinc Concentration (ug/l)								Copper Load (lbs/day)				Total Load Into Keswick (lbs/day)	% Contribution into Keswick		
	Shasta	SCDD			SCPP	Keswick Release			Shasta	SCDD	SCPP	Keswick Release		Shasta	SCDD	SCPP
	Assumed Conc.	SMC LSC-15	USBR	Avg	Assumed Conc.	SMC SRK-16	USBR	Avg								
06/01/96	2.7				2.6				189.1		13.9					
06/02/96	2.7				2.6				177.9		12.8					
06/03/96	2.7				2.6				207.3		12.6					
06/04/96	2.7		1710	1710	2.6				189.5	184.5	13.2		387.2	48.9%	47.6%	3.4%
06/05/96	2.7	1780		1780	2.6	<2			207.1	192.0	20.6		419.8	49.3%	45.7%	4.9%
06/06/96	2.7				2.6				208.4		18.7					
06/07/96	2.7				2.6				203.0		28.6					
06/08/96	2.7				2.6				179.4		28.2					
06/09/96	2.7				2.6				199.5		28.4					
06/10/96	2.7				2.6				183.6		27.7					
06/11/96	2.7				2.6				175.9		27.8					
06/12/96	2.7	1880	1680	1780	2.6	<2			173.5	192.0	29.0		394.5	44.0%	48.7%	7.3%
06/13/96	2.7				2.6				174.3		26.4					
06/14/96	2.7				2.6				185.0		26.5					
06/15/96	2.7				2.6				164.4		44.0					
06/16/96	2.7				2.6				168.2		40.5					
06/17/96	2.7				2.6				153.5		40.6					
06/18/96	2.7		2140	2140	2.6				169.1	230.9	40.4		440.4	38.4%	52.4%	9.2%
06/19/96	2.7	2110		2110	2.6	<2			140.2	227.6	40.3		408.1	34.3%	55.8%	9.9%
06/20/96	2.7				2.6				157.7		40.6					
06/21/96	2.7				2.6				137.3		41.4					
06/22/96	2.7				2.6				154.3		41.0					
06/23/96	2.7				2.6				150.0		40.3					
06/24/96	2.7				2.6				148.2		41.7					
06/25/96	2.7				2.6				121.8		41.5					
06/26/96	2.7	2360	2240	2300	2.6	<2			131.7	173.7	47.6		353.0	37.3%	49.2%	13.5%
06/27/96	2.7				2.6				139.2		45.8					
06/28/96	2.7				2.6				139.1		45.6					
06/29/96	2.7				2.6				140.0		47.3					
06/30/96	2.7				2.6				151.4		47.4					
													Minimum	34.3%	45.7%	3.4%
													Maximum	49.3%	55.8%	13.5%

Notes:
1) Assumed zinc concentrations:
Shasta = 2.7 ug/l
SCPP = 2.6 ug/l
2) Keswick sample results below the detection limit are not included in the loading calculation; "<" indicates result less than indicated detection limit.
3) Total load into Keswick equals sum of Shasta, SCDD and SCPP loads
4) Blank indicates data are not available
5) Ref. 1,7 and 8.

CIV-S-91-768 DFL JFM

DECLARATION OF
ANNE C. CONNELL

IRON MOUNTAIN TREATMENT PLANT

ACID MINE DISCHARGE

RESULTS - JANUARY 1995

DATE	GALLONS TREATED	INFLUENT-PPM pH	CU	ZN	CD	EFFLUENT-PPM pH	CU	ZN	CD	% REMOVAL CU	ZN	CD
01-Jan-95	149,760	1.3	128	536	3.7	6.7	0.020	0.020	0.005	99.984	99.996	99.865
02-Jan-95	156,096	1.3	129	545	3.8	6.8	0.020	0.020	0.005	99.984	99.996	99.868
03-Jan-95	156,096	1.3	133	576	3.9	6.8	0.020	0.020	0.005	99.985	99.997	99.872
04-Jan-95	158,112	1.3	134	582	4.3	6.4	0.020	0.023	0.005	99.985	99.996	99.884
05-Jan-95	158,112	1.3	132	560	3.8	6.7	0.020	0.045	0.005	99.985	99.992	99.868
06-Jan-95	158,112	1.4	130	558	3.8	6.8	0.079	2.800	0.024	99.939	99.498	99.368
07-Jan-95	166,032	1.4	131	528	3.8	7.1	0.026	0.650	0.005	99.980	99.877	99.868
08-Jan-95	175,536	1.4	149	507	3.7	6.8	0.020	0.042	0.005	99.987	99.992	99.865
09-Jan-95	964,515	1.3	215	722	4.7	6.7	0.020	0.079	0.005	99.991	99.989	99.894
10-Jan-95	1,664,400	0.8	559	1320	8.8	6.4	0.020	0.020	0.005	99.996	99.998	99.943
11-Jan-95	1,389,600	1.1	490	1110	7.6	6.6	N.S.A.	N.S.A.	N.S.A.	----	----	----
12-Jan-95	1,507,560	1.2	364	767	5.3	6.9	N.S.A.	N.S.A.	N.S.A.	----	----	----
13-Jan-95	1,182,750	1.2	340	740	5.0	6.6	0.021	0.076	0.005	99.994	99.990	99.900
14-Jan-95	1,975,490	1.2	324	753	5.0	6.6	0.020	0.067	0.005	99.994	99.991	99.900
15-Jan-95	1,440,000	1.2	301	755	5.2	6.3	0.020	0.075	0.005	99.993	99.990	99.904
16-Jan-95	1,224,000	1.2	298	771	5.0	7.0	0.037	0.721	0.006	99.988	99.906	99.880
17-Jan-95	972,000	1.2	305	779	5.4	6.8	0.055	2.870	0.024	99.982	99.632	99.556
18-Jan-95	864,000	1.2	321	788	5.7	10.5	0.031	0.110	0.005	99.990	99.986	99.912
19-Jan-95	806,400	1.2	330	793	5.4	6.2	0.023	0.160	0.005	99.993	99.980	99.907
20-Jan-95	748,800	1.2	331	784	5.9	9.3	0.046	0.250	0.005	99.986	99.968	99.915
21-Jan-95	698,400	1.1	332	785	5.5	6.6	0.030	0.120	0.005	99.991	99.985	99.909
22-Jan-95	576,000	1.1	341	852	6.2	7.0	0.042	0.210	0.005	99.988	99.975	99.919
23-Jan-95	504,000	1.1	349	948	6.6	6.7	0.036	0.210	0.005	99.990	99.978	99.924
24-Jan-95	685,440	1.1	288	713	5.4	6.6	0.035	0.200	0.005	99.988	99.972	99.907
25-Jan-95	1,035,360	1.2	283	719	5.0	8.9	0.350	0.870	0.007	99.876	99.879	99.860
26-Jan-95	1,051,200	1.2	298	790	5.8	8.9	0.150	0.410	0.005	99.950	99.948	99.914
27-Jan-95	829,440	1.1	347	1050	7.6	8.8	0.130	0.330	0.006	99.963	99.969	99.925
28-Jan-95	754,560	1.0	336	909	6.5	10.0	0.020	0.021	0.005	99.994	99.998	99.923
29-Jan-95	851,040	1.1	333	849	5.8	8.5	0.020	0.029	0.005	99.994	99.997	99.914
30-Jan-95	840,960	1.1	333	830	5.8	7.6	0.069	0.160	0.005	99.979	99.981	99.914
31-Jan-95	839,520	1.1	327	814	5.8	10.8	0.130	0.340	0.005	99.960	99.958	99.914

TOTAL 24,683,291

Approximately 5 hours to B.C.C.P., not included
pH taken from lowest recorded on PMCS.
No Sample Analyzed.

IRON MOUNTAIN TREATMENT PLANT

ACID MINE DISCHARGE

RESULTS - MARCH 1995

DATE	GALLONS TREATED	INFLUENT-PPM pH	INFLUENT-PPM CU	INFLUENT-PPM ZN	INFLUENT-PPM CD	EFFLUENT-PPM pH	EFFLUENT-PPM CU	EFFLUENT-PPM ZN	EFFLUENT-PPM CD	% REMOVAL CU	% REMOVAL ZN	% REMOVAL CD
01-Mar-95	506,844	1.2	322	643	4.6	10.1	0.020	0.020	0.005	99.994	99.997	99.891
02-Mar-95	455,736	1.1	343	856	6.2	9.6	0.020	0.020	0.005	99.994	99.998	99.919
03-Mar-95	252,590	1.1	334	694	5.0	8.6	0.020	0.020	0.005	99.994	99.997	99.900
04-Mar-95	342,450	1.2	328	694	5.1	10.6	0.020	0.020	0.005	99.994	99.997	99.902
05-Mar-95	347,300	1.2	322	691	4.9	10.9	0.020	0.020	0.005	99.994	99.997	99.898
06-Mar-95	341,625	1.2	314	681	4.9	9.0	0.020	0.020	0.005	99.994	99.997	99.898
07-Mar-95	357,800	1.2	306	652	4.7	9.2	0.020	0.020	0.005	99.993	99.997	99.894
08-Mar-95	453,256	1.1	321	910	6.5	8.6	0.020	0.020	0.005	99.994	99.998	99.923
09-Mar-95	800,680	1.1	229	589	4.2	8.9	0.020	0.020	0.005	99.991	99.997	99.881
10-Mar-95	1,191,510	1.1	241	703	5.0	6.6	0.020	0.095	0.005	99.992	99.986	99.900
11-Mar-95	1,464,762	1.1	234	746	5.1	6.7	0.026	0.420	0.005	99.989	99.944	99.896
12-Mar-95	1,392,138	1.2	242	756	5.2	6.5	0.048	1.100	0.021	99.980	99.854	99.596
13-Mar-95	1,213,702	1.2	243	735	5.0	7.7	0.059	1.100	0.022	99.976	99.850	99.560
14-Mar-95	1,815,296	1.3	225	718	4.9	9.1	0.024	0.490	0.009	99.989	99.932	99.810
15-Mar-95	1,287,488	1.2	261	815	5.5	9.1	0.024	0.280	0.005	99.991	99.966	99.905
16-Mar-95	1,733,672	1.1	315	947	6.4	9.6	0.020	0.110	0.005	99.994	99.988	99.922
17-Mar-95	1,778,464	1.2	312	911	6.3	6.8	0.020	0.110	0.005	99.994	99.988	99.921
18-Mar-95	1,647,672	1.2	339	1050	7.2	7.2	0.020	0.160	0.005	99.994	99.985	99.931
19-Mar-95	1,413,648	1.2	323	947	6.5	7.8	0.020	0.150	0.005	99.994	99.984	99.923
20-Mar-95	1,424,572	1.2	318	893	6.2	8.8	0.022	0.110	0.005	99.993	99.988	99.919
21-Mar-95	1,424,240	1.3	312	877	6.2	8.9	0.020	0.100	0.005	99.994	99.989	99.919
22-Mar-95	1,332,232	1.2	313	931	6.4	8.0	0.020	0.059	0.005	99.994	99.994	99.922
23-Mar-95	1,383,312	1.2	292	832	5.8	7.8	0.020	0.097	0.005	99.993	99.988	99.914
24-Mar-95	1,379,652	1.2	275	783	5.5	6.9	0.020	0.088	0.005	99.993	99.989	99.909
25-Mar-95	1,371,860	1.2	283	791	5.6	7.9	0.020	0.066	0.005	99.993	99.992	99.911
26-Mar-95	1,372,056	1.1	283	792	5.6	8.9	0.270	0.820	0.005	99.905	99.896	99.905
27-Mar-95	1,373,308	1.2	264	722	5.1	7.0	0.028	0.260	0.005	99.989	99.964	99.902
28-Mar-95	1,175,940	1.1	283	771	5.3	6.8	0.023	0.280	0.005	99.992	99.964	99.906
29-Mar-95	934,152	1.2	272	715	5.1	7.1	0.024	0.280	0.005	99.991	99.961	99.900
30-Mar-95	1,026,648	1.3	265	687	5.0	7.7	0.022	0.130	0.005	99.992	99.981	99.900
31-Mar-95	861,232	1.1	282	796	5.6	7.5	0.020	0.091	0.005	99.993	99.989	99.911
TOTAL	33,855,837											

IRON MOUNTAIN TREATMENT PLANT

ACID MINE DISCHARGE

RESULTS - FEBRUARY 1996

	GALLONS	INFLUENT-PPM				EFFLUENT-PPM				% REMOVAL		
DATE	TREATED	pH	CU	ZN	CD	pH	CU	ZN	CD	CU	ZN	CD
1-Feb-96	268,300	1.4	117	443	3.1	7.9	0.020	0.031	0.005	99.983	99.993	99.839
2-Feb-96	320,600	1.4	244	486	3.5	7.6	0.020	0.020	0.005	99.992	99.996	99.857
3-Feb-96	344,600	1.3	118	486	3.4	7.7	0.020	0.024	0.005	99.983	99.995	99.853
4-Feb-96	353,000	1.3	116	476	3.2	7.6	0.020	0.036	0.005	99.983	99.992	99.844
5-Feb-96	410,000	1.1	342	559	4.0	8.0	0.020	0.022	0.005	99.994	99.996	99.875
6-Feb-96	495,000	1.3	761	597	4.3	7.7	0.020	0.020	0.005	99.997	99.997	99.884
7-Feb-96	690,800	1.2	259	573	4.1	7.7	0.020	0.020	0.005	99.992	99.997	99.878
8-Feb-96	522,522	1.2	143	557	3.9	7.8	0.020	0.023	0.005	99.986	99.996	99.872
9-Feb-96	596,254	1.2	346	541	3.9	6.9	0.020	0.036	0.005	99.994	99.993	99.872
10-Feb-96	518,052	1.2	151	557	3.9	7.4	0.020	0.054	0.005	99.987	99.990	99.872
11-Feb-96	548,930	1.2	284	544	3.9	7.8	0.023	0.061	0.005	99.992	99.989	99.872
12-Feb-96	523,106	1.1	194	547	3.9	7.1	0.020	0.032	0.005	99.990	99.994	99.872
13-Feb-96	492,800	1.1	162	572	4.0	7.5	0.020	0.034	0.005	99.988	99.994	99.875
14-Feb-96	461,618	1.1	286	556	4.1	7.4	0.020	0.029	0.005	99.993	99.995	99.878
15-Feb-96	438,754	1.1	162	564	4.1	7.1	0.020	0.038	0.005	99.988	99.993	99.878
16-Feb-96	399,294	1.2	163	560	4.2	7.3	0.020	0.032	0.005	99.988	99.994	99.881
17-Feb-96	326,752	1.2	155	605	4.2	8.3	0.020	0.023	0.005	99.987	99.996	99.881
18-Feb-96	474,774	1.2	561	588	4.2	8.2	0.020	0.021	0.005	99.996	99.996	99.881
19-Feb-96	560,966	1.2	167	534	3.7	7.5	0.020	0.027	0.005	99.988	99.995	99.865
20-Feb-96	648,806	1.1	159	563	4.0	7.6	0.020	0.026	0.005	99.987	99.995	99.875
21-Feb-96	756,554	1.1	382	624	4.4	7.6	0.020	0.024	0.005	99.995	99.996	99.886
22-Feb-96	791,996	1.1	170	608	4.2	7.6	0.020	0.025	0.005	99.988	99.996	99.881
23-Feb-96	715,604	1.2	175	630	4.3	7.3	0.020	0.023	0.005	99.989	99.996	99.884
24-Feb-96	691,304	1.2	181	650	4.6	7.4	0.020	0.021	0.005	99.989	99.997	99.891
25-Feb-96	684,410	1.1	196	655	4.5	7.5	0.020	0.022	0.005	99.990	99.997	99.889
26-Feb-96	685,014	1.1	192	666	4.6	7.5	0.020	0.026	0.005	99.990	99.996	99.891
27-Feb-96	686,240	1.2	194	659	4.6	7.4	0.020	0.020	0.005	99.990	99.997	99.891
28-Feb-96	688,553	1.2	189	642	4.6	7.5	0.020	0.020	0.005	99.989	99.997	99.891
29-Feb-96	683,048	1.1	193	650	4.5	7.6	0.020	0.020	0.005	99.990	99.997	99.889

TOTAL 15,777,651

IRON MOUNTAIN TREATMENT PLANT

ACID MINE DISCHARGE

RESULTS - JUNE 1996

DATE	GALLONS TREATED	INFLUENT-PPM pH	INFLUENT-PPM CU	INFLUENT-PPM ZN	INFLUENT-PPM CD	EFFLUENT-PPM pH	EFFLUENT-PPM CU	EFFLUENT-PPM ZN	EFFLUENT-PPM CD	% REMOVAL CU	% REMOVAL ZN	% REMOVAL CD
1-Jun-96	293,167	1.1	181	720	5.1	7.7	0.020	0.020	0.0050	99.989	99.997	99.902
2-Jun-96	291,525	1.1	182	717	5.1	7.9	0.020	0.020	0.0050	99.989	99.997	99.902
3-Jun-96	291,254	1.1	190	717	5.1	7.6	0.020	0.020	0.0050	99.989	99.997	99.902
4-Jun-96	365,916	1.1	339	885	6.3	7.7	0.020	0.028	0.0050	99.994	99.997	99.921
5-Jun-96	326,780	1.1	290	818	5.9	7.6	0.020	0.020	0.0050	99.993	99.998	99.915
6-Jun-96	328,358	1.1	292	740	5.2	7.7	0.020	0.020	0.0050	99.993	99.997	99.904
7-Jun-96	313,200	1.0	273	749	5.1	7.9	0.020	0.020	0.0050	99.993	99.997	99.902
8-Jun-96	278,800	1.2	185	707	5.1	7.9	0.020	0.020	0.0050	99.989	99.997	99.902
9-Jun-96	277,200	1.2	177	690	5.0	7.9	0.020	0.036	0.0050	99.989	99.995	99.900
10-Jun-96	323,400	1.2	178	678	4.8	7.8	0.020	0.020	0.0050	99.989	99.997	99.896
11-Jun-96	307,700	1.2	251	695	5.0	7.8	0.020	0.020	0.0050	99.992	99.997	99.900
12-Jun-96	278,500	1.1	174	685	4.8	7.9	0.020	0.020	0.0050	99.989	99.997	99.896
13-Jun-96	284,247	1.2	170	661	4.7	7.8	0.020	0.020	0.0050	99.988	99.997	99.894
14-Jun-96	272,638	1.2	172	662	4.6	7.8	0.020	0.020	0.0050	99.988	99.997	99.891
15-Jun-96	257,343	1.1	170	652	4.5	7.9	0.020	0.020	0.0050	99.988	99.997	99.889
16-Jun-96	253,178	1.0	167	730	5.0	7.9	0.020	0.020	0.0050	99.988	99.997	99.900
17-Jun-96	234,735	1.1	168	720	4.9	7.1	0.020	0.020	0.0050	99.988	99.997	99.898
18-Jun-96	258,183	1.1	162	681	4.6	7.8	0.020	0.044	0.0050	99.988	99.994	99.891
19-Jun-96	256,716	1.2	163	672	4.6	7.8	0.020	0.020	0.0050	99.988	99.997	99.891
20-Jun-96	257,787	1.2	168	682	4.7	7.9	0.020	0.020	0.0050	99.988	99.997	99.894
21-Jun-96	213,150	1.1	188	944	6.5	7.8	0.020	0.020	0.0050	99.989	99.998	99.923
22-Jun-96	149,085	1.0	213	1200	8.2	7.7	0.020	0.020	0.0050	99.991	99.998	99.939
23-Jun-96	160,611	1.1	199	1110	7.6	7.8	0.020	0.020	0.0050	99.990	99.998	99.934
24-Jun-96	189,559	1.1	185	886	6.1	7.6	0.020	0.020	0.0050	99.989	99.998	99.918
25-Jun-96	257,298	1.2	159	644	4.4	7.6	0.020	0.026	0.0050	99.987	99.996	99.886
26-Jun-96	255,217	1.3	156	641	4.4	7.6	0.020	0.020	0.0050	99.987	99.997	99.886
27-Jun-96	215,458	1.1	173	838	5.6	7.6	0.020	0.020	0.0050	99.988	99.998	99.911
28-Jun-96	195,933	1.1	174	804	5.5	7.3	0.020	0.020	0.0050	99.989	99.998	99.909
29-Jun-96	257,748	1.1	155	627	4.3	7.3	0.020	0.020	0.0050	99.987	99.997	99.884
30-Jun-96	257,556	1.1	156	624	4.2	7.6	0.020	0.020	0.0050	99.987	99.997	99.881
TOTAL	7,902,242											

IRON MOUNTAIN TREATMENT PLANT

ACID MINE DISCHARGE

RESULTS - DECEMBER 1996

DATE	GALLONS TREATED	INFLUENT-PPM pH	INFLUENT-PPM CU	INFLUENT-PPM ZN	INFLUENT-PPM CD	EFFLUENT-PPM pH	EFFLUENT-PPM CU	EFFLUENT-PPM ZN	EFFLUENT-PPM CD	% REMOVAL CU	% REMOVAL ZN	% REMOVAL CD
1-Dec-96	170,013	1.5	156	674	5.7	8.0	0.020	0.020	0.005	99.987	99.997	99.913
2-Dec-96	162,183	1.3	159	708	5.9	7.9	0.020	0.020	0.005	99.987	99.997	99.915
3-Dec-96	55,879	1.3	158	718	6.0	7.6	0.020	0.020	0.005	99.987	99.997	99.917
4-Dec-96	184,056	1.3	153	872	5.8	8.2	0.020	0.020	0.005	99.987	99.998	99.914
5-Dec-96	257,961	1.4	158	661	5.5	9.5	0.040	0.020	0.005	99.975	99.997	99.909
6-Dec-96	156,694	1.4	148	516	5.2	8.5	0.020	0.020	0.005	99.986	99.996	99.903
7-Dec-96	198,281	1.4	123	506	4.3	7.8	0.027	0.020	0.005	99.978	99.996	99.882
8-Dec-96	177,592	1.5	143	543	4.6	7.7	0.020	0.020	0.005	99.986	99.996	99.890
9-Dec-96	264,329	1.4	118	380	3.4	6.7	0.020	0.020	0.005	99.983	99.995	99.853
10-Dec-96	305,667	1.3	164	568	4.8	6.7	0.020	0.020	0.005	99.988	99.996	99.896
11-Dec-96	419,830	1.2	167	677	5.8	6.2	0.020	0.020	0.005	99.988	99.997	99.914
12-Dec-96	386,346	1.1	170	699	5.8	6.6	0.020	0.020	0.005	99.988	99.997	99.913
13-Dec-96	442,324	1.1	175	918	7.5	7.0	0.020	0.020	0.005	99.989	99.998	99.933
14-Dec-96	422,520	1.1	169	882	7.6	7.2	0.020	0.020	0.005	99.988	99.998	99.934
15-Dec-96	404,379	1.2	168	849	6.9	7.3	0.020	0.020	0.005	99.988	99.998	99.928
16-Dec-96	384,653	1.1	157	742	6.1	7.1	0.020	0.020	0.005	99.987	99.997	99.918
17-Dec-96	381,364	1.0	167	761	6.3	7.6	0.020	0.020	0.005	99.988	99.997	99.921
18-Dec-96	353,901	1.2	168	728	6.1	7.2	0.020	0.020	0.005	99.988	99.997	99.918
19-Dec-96	340,372	1.2	169	707	5.9	7.6	0.020	0.020	0.005	99.988	99.997	99.915
20-Dec-96	357,976	1.3	167	678	5.7	7.5	0.020	0.020	0.005	99.988	99.997	99.912
21-Dec-96	339,143	1.3	162	650	5.5	7.1	0.020	0.020	0.005	99.988	99.997	99.909
22-Dec-96	318,751	1.2	157	619	5.2	7.5	0.020	0.020	0.005	99.987	99.997	99.905
23-Dec-96	301,257	1.2	150	581	4.9	7.3	0.020	0.020	0.005	99.987	99.997	99.898
24-Dec-96	297,206	1.1	153	588	5.0	7.8	0.020	0.020	0.005	99.987	99.997	99.899
25-Dec-96	299,264	1.2	152	571	4.8	7.8	0.020	0.020	0.005	99.987	99.996	99.896
26-Dec-96	302,788	1.1	145	531	4.5	7.7	0.020	0.020	0.005	99.986	99.996	99.890
27-Dec-96	300,371	1.2	140	502	4.2	7.5	0.020	0.020	0.005	99.986	99.996	99.882
28-Dec-96	312,879	1.2	139	497	4.2	7.5	0.020	0.020	0.005	99.986	99.996	99.881
29-Dec-96	348,681	1.2	139	443	3.8	7.6	0.020	0.020	0.005	99.986	99.995	99.867
30-Dec-96	488,269	1.1	127	480	4.1	7.4	0.020	0.020	0.005	99.984	99.996	99.877
31-Dec-96	1,559,571	1.1	157	595	4.9	7.6	0.020	0.020	0.005	99.987	99.997	99.898
TOTAL	10,694,500											

IRON MOUNTAIN TREATMENT PLANT

ACID MINE DISCHARGE

RESULTS - JANUARY 1997

	GALLONS	INFLUENT-PPM				EFFLUENT-PPM				% REMOVAL		
DATE	TREATED	pH	CU	ZN	CD	pH	CU	ZN	CD	CU	ZN	CD
1-Jan-97	2,036,700	1.1	257	685	5.9	7.3	0.020	0.022	0.005	99.992	99.997	99.915
2-Jan-97	2,530,300	1.0	279	684	5.9	7.5	0.042	0.112	0.005	99.985	99.984	99.915
3-Jan-97	2,146,000	0.9	367	936	7.9	7.6	0.020	0.029	0.005	99.995	99.997	99.937
4-Jan-97	1,497,500	1.0	351	913	7.9	7.6	0.020	0.027	0.005	99.994	99.997	99.937
5-Jan-97	1,239,500	1.0	340	887	7.8	8.1	0.022	0.073	0.005	99.994	99.992	99.936
6-Jan-97	1,083,500	0.9	332	873	7.7	7.9	0.020	0.037	0.005	99.994	99.996	99.935
7-Jan-97	995,500	0.9	302	797	7.1	8.2	0.020	0.020	0.005	99.993	99.997	99.929
8-Jan-97	954,000	1.0	289	750	6.7	7.8	0.020	0.031	0.005	99.993	99.996	99.926
9-Jan-97	919,628	9.0	285	740	6.7	7.6	0.020	0.042	0.005	99.993	99.994	99.925
10-Jan-97	882,422	1.1	276	711	6.5	7.5	0.020	0.028	0.005	99.993	99.996	99.922
11-Jan-97	875,214	1.1	277	701	6.4	7.6	0.020	0.020	0.005	99.993	99.997	99.922
12-Jan-97	816,582	1.3	269	673	6.1	7.5	0.020	0.040	0.005	99.993	99.994	99.918
13-Jan-97	683,362	1.1	256	643	5.9	7.1	0.020	0.036	0.005	99.992	99.994	99.915
14-Jan-97	816,144	1.1	261	644	5.9	7.5	0.020	0.022	0.005	99.992	99.997	99.915
15-Jan-97	683,218	1.0	260	630	5.8	7.4	0.020	0.025	0.005	99.992	99.996	99.913
16-Jan-97	697,104	1.1	250	628	5.3	7.3	0.020	0.037	0.005	99.992	99.994	99.905
17-Jan-97	695,688	1.2	240	617	5.2	7.0	0.020	0.036	0.005	99.992	99.994	99.904
18-Jan-97	669,008	1.2	220	562	4.8	7.0	0.020	0.070	0.005	99.991	99.988	99.89[illegible]
19-Jan-97	679,816	1.1	244	616	5.2	7.3	0.020	0.053	0.005	99.992	99.991	99.905
20-Jan-97	704,808	1.1	226	570	4.9	6.9	0.043	0.120	0.005	99.981	99.979	99.897
21-Jan-97	715,494	1.1	223	564	4.8	7.0	0.057	0.171	0.005	99.974	99.970	99.897
22-Jan-97	762,668	1.0	229	575	4.9	6.7	0.087	0.221	0.005	99.962	99.962	99.897
23-Jan-97	665,932	1.1	234	565	4.8	7.0	0.113	0.291	0.005	99.952	99.948	99.895
24-Jan-97	604,064	1.1	216	547	4.6	7.1	0.020	0.093	0.005	99.991	99.983	99.891
25-Jan-97	625,578	1.1	199	504	4.3	7.1	0.049	0.149	0.005	99.975	99.970	99.883
26-Jan-97	686,110	1.2	224	571	4.7	6.9	0.042	0.111	0.005	99.981	99.981	99.894
27-Jan-97	682,688	1.1	234	723	5.7	7.1	0.132	0.297	0.005	99.944	99.959	99.912
28-Jan-97	801,302	1.2	223	679	5.5	7.1	0.051	0.207	0.005	99.977	99.970	99.908
29-Jan-97	850,960	1.2	206	642	5.2	7.0	0.040	0.183	0.005	99.981	99.971	99.904
30-Jan-97	890,760	1.1	196	643	5.3	6.9	0.045	0.202	0.005	99.977	99.969	99.906
31-Jan-97	770,294	1.2	211	681	5.6	7.1	0.186	0.579	0.005	99.912	99.915	99.905

TOTAL 29,661,844

ATTACHMENT 4

COPPER AND ZINC CONCENTRATIONS

SHASTA DAM AND SPRING CREEK POWERHOUSE

Metal Concentration in Spring Creek Powerhouse and Shasta Dam Releases

PREPARED FOR: Rick Sugarek/ EPA

PREPARED BY: John Spitzley, CH2M HILL

At your request, CH2M HILL analyzed copper and zinc concentration data obtained from analytical testing conducted on discharges from Shasta Dam and the Spring Creek Powerhouse. The data sources and the time period during which the data were collected consist of the following:

- California Regional Water Quality Control Board (CRWQCB) Data, 1993
- CH2M HILL for U.S. EPA, 1994 to February 1997
- Stauffer Management Company (SMC), 1995 to January 1997

The average total and dissolved copper and zinc concentrations for each data set are listed in Table 1. These averages were calculated using two methods for handling reported nondetect concentrations. The first method assumes that the actual sample concentration of the nondetects is equal to the detection limit. The second method assumes that the actual sample concentration of the nondetects is equal to one-half the detection limit. The table lists the number of detects and nondetects for each data set.

TABLE 1
Summary of Copper and Zinc Concentrations

Location	Parameter	Data Source	Average Concentration Using the Detection Limit (µg/L)	Average Concentration Using One-Half the Detection Limit (µg/L)	Number of Detects	Number of Nondetects
Spring Creek Powerhouse						
	Dissolved Copper					
		RWQCB	1.3	1.3	10	0
		CH2M	1.1	1.0	22	9
		SMC	2.0	1.1	5	84
	Total Copper					
		RWQCB	2.1	2.1	10	0
		CH2M	2.3	2.2	24	5
		SMC	2.8	2.1	30	70
	Dissolved Zinc					
		RWQCB	4.0	3.3	5	5
		CH2M	4.5	2.6	3	31
		SMC	5.2	3.3	26	64
	Total Zinc					
		RWQCB	7.0	7.0	10	0
		CH2M	6.3	5.0	13	19
		SMC	7.5	5.9	47	54
Shasta Dam						
	Dissolved Copper					
		RWQCB	1.9	1.9	26	2
		CH2M	1.4	1.3	42	12
		SMC	2.1	1.2	37	186
	Total Copper					
		RWQCB	2.7	2.7	19	0
		CH2M	3.5	3.4	52	5
		SMC	4.0	3.5	122	104
	Dissolved Zinc					
		RWQCB	4.4	3.9	21	7
		CH2M	5.2	3.9	10	46
		SMC	3.8	2.7	80	142
	Total Zinc					
		RWQCB	9.9	9.9	19	0
		CH2M	12.6	11.7	42	15
		SMC	8.6	7.9	165	59

Review of Historical Fact Report

PREPARED FOR: Rick Sugarek/U.S. EPA

PREPARED BY: Ray Prettyman/CH2M HILL

Description of Document

This document, the *Historical Fact Report*, dated August 8, 1994, was submitted by Stauffer Management Company (SMC) for inclusion in the public record. It presents some Shasta Dam and Spring Creek Debris Dam (SCDD) flow data and Sacramento River copper data for five major SCDD spills. It also presents arguments against the proposed enlargement of SCDD to 15,000 acre-feet.

Major Findings or Major Review Comments in Document

SMC contends that all the spills which have occurred from SCDD could have been avoided if the U.S. Bureau of Reclamation (USBR) had used available flows from Shasta Dam to lower the volume of acid mine drainage in Spring Creek Reservoir instead of allowing the reservoir to fill during periods of moderate rainfall and then spill during larger storms. SMC states that at no time during any spill event is there evidence that the dissolved copper concentrations exceeded 14 parts per billion, which is a level that SMC contends is not harmful to fish.

According to SMC, the U.S. Environmental Protection Agency (EPA) ignored the available hardness data in the Sacramento River in selecting the Basin Plan objectives as applicable or relevant and appropriate requirements (ARARs). EPA also ignored available data on metals precipitation in Keswick Reservoir that indicate more precipitation than that predicted by the EPA model.

SMC also contends that EPA failed to use available data to estimate the full effect of stratification in the SCDD and has arbitrarily inflated the predicted size of the SCDD enlargement.

Lastly, according to SMC, EPA has ignored the substantial portion of the metals loading in the Sacramento River contributed by sources that do not drain into SCDD.

Response to Major Findings in Document

The contentions presented in this document were arguments against the enlargement of Spring Creek Debris Dam. Even though EPA expects that additional control of Iron Mountain Mine (IMM) area sources will make it unnecessary to enlarge SCDD, certain of these arguments are addressed below.

USBR operations of Keswick Reservoir rely on the reservoir as a forebay for the Shasta Dam powerhouse and the Spring Creek Powerhouse operations. Waters are stored in Keswick until they can be released under Central Valley Project (CVP) operations criteria for the flow regime required for the Sacramento River system. Even though it may appear that waters from Shasta Dam are available to dilute SCDD flows, these waters may not be available under CVP operations criteria.

Even though SMC contends that there have been no spills from SCDD that harmed fish, there have been 39 documented fish kills near Redding since 1940, and there have been observations of adult steelhead mortalities near Redding, attributable to metal contamination from IMM since installation of the SCDD. Additionally, the California Department of Fish and Game has conducted bioassay tests to determine metals concentrations allowable for fisheries in the Sacramento River.

In the 1992 IMM *Environmental Endangerment Assessment* (EA), Table 3-3 listed documents reporting fish kills since 1940 (through 1978). Additionally, an incident in 1899-1900 was cited. These reported kills are referenced starting with a 1899-1900 incident cited by H. W. Smith: *Report on the Inquiry Respecting Food Fishes and the Fishing Grounds*. In: the Report of the Commissioner of Fish and Fisheries for the Year Ending June 30, 1901. Most of the remaining reports are from California Department of Fish and Game Region 1 (Redding) files. Since 1940 there have been fish kills reported in the following years:

- 1940
- 1944
- 1945
- 1948
- 1949
- 1950 through 1957 (in 7 out of 8 years, including 2 incidents in 1955 and 7 incidents in 1957)
- Three incidents in 1959
- 1960
- 1961
- Two incidents in 1962
- Two incidents in 1964
- Three incidents in 1966
- 1967
- 1969
- 1978

The majority of the reported kills since 1940 have resulted in counted or estimated numbers of fish killed and include salmon, steelhead, and rainbow trout. Reported number of dead fish range from 5 salmon (1964) to an estimate of 100,000 chinook salmon fingerlings or other species (1955 and 1967). In 11 of these reported fish kill incidents, copper and zinc concentrations were measured and reported during the fish kill incident (Table 3-6 in the 1992 EA).

Also, since 1979, 13 spill intervals of varying periods of time have occurred in which CDFG estimated salmonid fry kills occurred in the Sacramento River downstream of Keswick (EA, 1992). These estimated mortalities, ranging from 10 to 50 percent of the fry present, were derived from lethality data determined from laboratory bioassay studies and actual measured concentrations obtained during 32 individual spill events during the 13 reported spill periods (Table 3-7, 1992 EA).

Of the reported fish kills since 1940, at least eight incidents have occurred since the Spring Creek Debris Dam was constructed in 1963. It must be noted that while SCDD has lessened the impacts of acute toxicity events occurring in the Sacramento River since its construction, it continues to act to increase the total duration of fish exposure to copper and zinc at chronically toxic concentrations.

EPA has not ignored hardness. The soluble metal toxicity equations used in the State Basin Plan standards (SBPS), used as ARARs for IMM, contain a factor for hardness so that as hardness increases or decreases, compliance levels of soluble metals increase or decrease. EPA's 1996 *Water Management Feasibility Study Addedum* presents data which demonstrate that hardness decreases significantly during storm events, resulting in a decrease in the SBPS of 5.6 μg/l for copper.

EPA has performed additional data acquisition studies to better define metal precipitation rates in Keswick Reservoir. Laboratory and field precipitation studies have resulted in a variable precipitation rate, which is a function of total copper and zinc concentrations, being included in the IMM Water Quality Model. This variable precipitation rate allows for a greater precipitation rate at higher copper concentrations.

EPA and other government agencies have not ignored other sources contributing metals to the Sacramento River. Mines in this area have been required to implement source control measures to substantially reduce their release of metals.

As presented by the SMC consultant report, *Iron Mountain Mine Off-Site Metals Loading During 1995 Storms*, Morrison Knudsen Corporation, September 1995, 90 percent, or more, of the metal load discharged from Keswick Dam during the early January 1995 storm originated from Spring Creek Debris Dam downstream of Iron Mountain.

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
75 Hawthorne Street
San Francisco, CA 94105
MEMORANDUM

TO: File

FROM: Rick Sugarek, Remedial Project Manager

SUBJECT: Analysis of SCDD Operation Efficiency for Use in the Iron Mountain Mine Water Quality Model (IMM WQM)

This memorandum summarizes EPA's analysis of factors related to estimating the efficiency of practicable Spring Creek Debris Dam (SCDD) release operations to assure dilution of Iron Mountain Mine (IMM) heavy metal discharges to safe levels with Sacramento River flows. The efficiency of SCDD operations is one input to the model EPA uses to evaluate the relative performance of remedial alternatives that rely, in part, on water management as a component in an interim or final remedial strategy for IMM AMD discharges.

EPA's interim remedial action currently relies on efficient SCDD operations to minimize the impacts of the continuing IMM heavy metal discharges on the environment.

In evaluating the relative protectiveness of additional remedial alternatives under consideration for remedy selection in the next phase of cleanup actions, EPA relies on the IMM Water Quality Model (WQM) to model the relative performance of the alternatives in reducing the frequency of AMD spills from the SCDD, the metal concentrations of the AMD spills and the duration of exceedances of the SBPS. This evaluation of the relative performance of remedial alternatives is an important means to compare potential remedial alternatives, to project the expected improvement in site conditions with implementation of a remedial alternative, and to assess the need for additional actions.

Additionally, full control of the IMM heavy metal discharges may not be technically practicable in a final remedy for the Site. In a future remedy selection decision EPA may determine that dilution of some amount of the IMM heavy metal discharges is required as part of the final remedy. Efficient SCDD operations could be required under such a water management cleanup approach.

It is, therefore, important to characterize the data requirements, data uncertainty and other limitations associated with practicable efficient operation of the SCDD. The SCDD operational data requirements, data uncertainty and other limitations can then be taken into consideration in designing an operational strategy to assure attainment of protective State Basin Plan Standards (SBPS) as a component of EPA's interim and final IMM remedies.

SCDD Operations Concept

Efficient operation of the SCDD outlet works to manage the safe release of IMM contaminated Spring Creek waters to Keswick Reservoir requires:

- Field sampling to acquire extensive water quality and surface water flow data to adequately characterize all surface water inflows to the Keswick Reservoir

- Analysis of water samples for key water quality parameters for determining the appropriate SCDD release rate, including the dissolved copper and zinc concentrations, hardness, and chemical parameters related to metal precipitation

- The performance of the Keswick Reservoir mass balance (including an estimate of the extent to which metals may precipitate from the dissolved form to particulate form) to determine the allowable SCDD release that would assure attainment of the protective SBPS below Keswick Dam

- Decision making regarding the need for adjustment to SCDD operational controls in coordination with all interrelated CVP operations

- Making changes to the operational settings of the SCDD outlet works gates to implement the appropriate controls, and verifying that the changes have been correctly implemented.

Effective and timely implementation of each of these elements is critical to the success of SCDD release operations. Each of these efforts is discussed in the following sections.

Field Sampling Program

Field sampling to support SCDD release operations requires the performance of field sampling over a wide area, under adverse storm conditions while adhering to rigorous protocols to assure the representativeness of water quality samples taken from surface waters during intense storms and often under dangerous flood conditions. Support for SCDD operations also requires accurate measurement, or estimate, of CVP facility releases and Keswick Reservoir storm inflows.

Objectives

The objectives of the field sampling program to support SCDD operations are to:

- Acquire representative samples of surface water for water quality analysis for inflows to Spring Creek Reservoir, waters within Spring Creek Reservoir, CVP facility releases into Keswick Reservoir, all accretion inflows to Keswick Reservoir, waters within Keswick Reservoir (including the Spring Creek arm of Keswick Reservoir (SCAKR)), and the Keswick Dam releases

- Acquire accurate surface water flow measurements/estimates for Spring Creek Reservoir inflows, CVP facility releases into Keswick Reservoir, all accretion inflows to Keswick Reservoir and the Keswick Dam releases

- Deliver the samples to the laboratory for analysis to expedite turn-around time in support of responsive operational decision making in highly variable storm conditions

- Report the results of the flow measurements/estimates to operational personnel to support responsive operational decision making in highly variable storm conditions

Key Tasks

The data acquired in the field sampling program provide critical support for:

- Characterizing the quality of inflows to Spring Creek Reservoir, waters within Spring Creek Reservoir, CVP facility releases into Keswick Reservoir, all surface water inflows to Keswick Reservoir, waters within Keswick Reservoir (including SCAKR), and the Keswick Dam releases

- Measuring/estimating the flow rates and metal loads associated with inflows to Spring Creek Reservoir, CVP facility releases into Keswick Reservoir, all accretion inflows to Keswick Reservoir, and the Keswick Dam releases

- Determining the metal precipitation rates in Keswick Reservoir

- Monitoring the hardness of the Keswick Dam releases to support a determination of the SBPS (which are adjusted on the basis of hardness)

- Accurately performing the Keswick Reservoir mass balance

- Supporting responsive operational decision making

- Monitoring to assure compliance with the SBPS and the safe release of the IMM discharges

EPA has developed a "Storm Sampling Program to Support Spring Creek Debris Dam Operations" to provide a basic concept of the scope of the field sampling and analytical services effort required to support SCDD operations. EPA has also estimated the associated costs for field sampling labor and analytical services. The field sampling program is presented in Appendix A. This technical memorandum presents three options for the SCDD operations support sampling program that differ primarily in the frequency of sampling to be performed and cost. If data is available on a frequent basis with rapid turn-around time on the analytical analyses, it should be possible to operate the SCDD at higher operation efficiencies. With less frequent data, more conservative operational assumptions would be necessary in order to assure that the protective SBPS were not exceeded in the Sacramento River, particularly under highly variable conditions experienced during storms.

Water Quality

- The primary water quality parameter, central to determining the appropriate amount of IMM contaminated waters that can safely be released from the SCDD, is the dissolved copper content. Past EPA IMM WQM modeling efforts have shown that the high copper concentrations of the IMM contaminated Spring Creek waters stored in the Spring Creek Reservoir generally control the allowable safe release of these waters from the SCDD.

- Under certain conditions, dissolved zinc concentrations control the allowable safe release of IMM contaminated waters from the SCDD.

- Based upon the progress of EPA's remedial action to date, cadmium concentrations are not expected to control the allowable safe release of IMM contaminated waters from the SCDD.

- Because the SBPS vary with the hardness of the surface water, it is important to determine the hardness of the receiving water in order to appropriately determine the proper standard.

- Because a significant amount of the dissolved copper and zinc in the contaminated Spring Creek waters precipitate from "dissolved" to "particulate" form upon dilution, it is important to measure other water quality parameters, such as aluminum and iron content, to support an analysis of the estimated metal precipitation rates under conditions at the time.

- At times of high accretion flows, it is important to closely monitor the characteristics of these flows. The hardness, alkalinity, organic carbon content or suspended particulate matter in these flows may, at times, significantly impact conditions in Keswick Reservoir, including the appropriate SBPS and/or the observed rates of metal precipitation in Keswick Reservoir. Further study is required.

- Sampling dilute CVP facility releases, surface water inflows to Keswick Reservoir and Keswick Dam releases requires a very high level of quality assurance and quality control (QA/QC) to prevent sample contamination and assure proper analyses of these waters with low metal levels.

- Rigorous field sampling protocols are necessary to assure that representative surface water quality samples are obtained, particularly during storm periods with significant accretion flows.

Surface Water Inflow and CVP Facility Release Rates

- The primary flow components of the Keswick Reservoir water balance are the releases from CVP facilities, including Shasta Dam, SCPH, SCDD and Keswick Dam.

- Flow estimates can be obtained from CVP operational information for inflows to Spring Creek Reservoir, Shasta Dam releases, SCPH releases, SCDD releases, and the Keswick Dam releases.

- On occasion, the Keswick Reservoir accretion flows may provide the dominant component, or a major component, of the Keswick Reservoir water balance.

- Direct flow measurement of the Keswick Reservoir accretion flows is possible but would be difficult. These flows could be estimated from CVP operational information related to SCDD inflows and an area apportionment approach. This approach has been shown to be reasonably reliable in past EPA studies.

Issues

- Water quality samples taken at the current sampling point below Keswick Dam may not be representative of conditions in the Sacramento River, particularly during period of high side flow from accretion. Further study needs to be performed to define the extent to which measurements at this sampling point may be impacted by side-flow.

- This sample point is important for determining compliance with the protective SBPS and for setting SCDD release operations. An underestimate of the true copper concentration at this location would result in noncompliance (a higher true copper concentration in the portions of the river that were not diluted by the side flow).

- Strong Sacramento River flow, during storms, often creates dangerous conditions for sampling on the river below Keswick Dam. Mid-stream sampling during storms does not appear to be a practicable option to assure representative samples.

- It is difficult to take representative samples from the major accretion flows during storms due to the peak nature of the inflows to Keswick Reservoir and difficulty in performing sampling at these times.

- Historic data indicate that water quality measurements in the Sacramento River below Keswick Dam (pH, hardness and copper and zinc concentrations) vary widely over short periods of time during storm events. An intensive field sampling program is required to fully characterize these fluctuations for consideration in operational decision making.

- Historic data indicate that metal precipitation rates in Keswick Reservoir (copper and zinc) vary widely over short periods of time during storm events. An intensive field sampling program is required to fully characterize these fluctuations for consideration in operational decision making.

- Historic data indicate that the metal concentrations (copper and zinc) in the inflow and metal stratification effects in Spring Creek Reservoir vary widely over short periods of time during storm events. An intensive field sampling program is required to fully characterize these fluctuations for consideration in operational decision making.

- Historic data indicate that the water quality of accretion flows (pH, hardness and copper and zinc concentrations) varies widely over short periods of time during storm events. An intensive field sampling program is required to fully characterize these fluctuations for consideration in operational decision making.

- If CVP operational reporting is to be relied on for performing the Keswick Reservoir mass balance, additional QA/QC procedures need to be implemented to assure the accuracy and reliability of this operational report.

- Estimation of the flow rates of the major accretion flows by comparison to the Spring Creek Reservoir inflows introduces some uncertainty into the performance of the Keswick Reservoir mass balance. Field measurement of the major accretion flows and/or field observations could be relied upon to reduce this uncertainty.

- Performance of reservoir studies in SCAKR to acquire data regarding metal precipitation is important for efficient SCDD operation, but is expected to be difficult under storm conditions that are critical to the successful operation of the SCDD.

Although metal precipitation rates are expected to vary significantly over short periods of time during storm events, only limited SCAKR sampling could be expected to be physically possible.

- Performance of reservoir studies in SCR to acquire data regarding metal stratification is important for efficient SCDD operation, but is expected to be difficult under storm conditions that are critical to the successful operation of the SCDD. Although metal concentrations are expected to vary significantly with depth and over short periods of time during storm events, only limited reservoir sampling could be expected to be physically possible.

- Because of the wide-spread area over which samples must be taken, it would be necessary to rely on multiple sampling crews. Additionally, sample couriers would be necessary to assure that samples are delivered to the laboratory expeditiously for analysis on a rapid turn-around time basis.

Analytical Program

The water quality analysis program to support SCDD release operations requires the performance of analytical testing on multiple samples for multiple chemical parameters on a rapid turn-around basis while adhering to rigorous protocols to assure the accuracy and precision of testing results for samples with extremely dilute metal levels.

Objectives

The objectives of the analytical program to support SCDD operational decision making are to:

- Produce highly accurate and precise analyses of samples of surface water inflows to Spring Creek Reservoir, surface water within Spring Creek Reservoir, CVP facility releases into Keswick Reservoir, all accretion inflows to Keswick Reservoir, surface water within Keswick Reservoir, and the Keswick Dam releases

- Perform the testing and report the results of the laboratory analyses to operational personnel within rapid turn-around time constraints to support responsive operational decision making in highly variable storm conditions.

Key Tasks

The analytical data provide critical support for:

- Characterizing the quality of inflows to Spring Creek Reservoir, surface water within Spring Creek Reservoir, CVP facility releases into Keswick Reservoir, all accretion inflows to Keswick Reservoir, surface water within Keswick Reservoir, and the Keswick Dam releases

- Determining the metal precipitation rates in Keswick Reservoir

- Monitoring the hardness of the Keswick Dam releases to support a determination of the SBPS (which are adjusted on the basis of hardness)

- Accurately performing the Keswick Reservoir mass balance
- Monitoring to assure compliance with the SBPS and the safe release of the IMM discharges

EPA has developed a "Storm Sampling Program to Support Spring Creek Debris Dam Operations" to provide a basic concept of the scope of the field sampling and analytical services effort required to support SCDD operations. EPA has also estimated the associated costs for field sampling labor and analytical services. The analytical program is presented in Appendix A. A key factor in highly efficient SCDD release operations is analytical turn-around time. For highly efficient operations under the highly variable conditions of storms, it is critical that analytical turn-around time be reduced to the maximum extent possible without compromizing the quality of the analyses.

Issues

- Analyses for metal concentrations in the clean surface water releases from CVP facilities, particularly those from Shasta Dam and the SCPH, require protocols that have detection limits of 0.5 ppb copper and 2 ppb zinc. These protocols require a high level of QA/QC and longer analytical turn-around time than other less rigorous analytical methods.
- Analyses for metal concentrations in the Keswick Reservoir accretion flows (which can vary from very low levels of metal, 1 ppb copper or less, to levels approaching the SBPS of 5.6 ppb copper (at 40 ppm hardness), also require protocols that have detection limits of 0.5 ppb copper and 2 ppb zinc. These protocols require a high level of QA/QC and longer analytical turn-around time than other less rigorous analytical methods.
- Analyses for metal concentrations in the Keswick Dam releases (which can vary from very low levels of metal, 2 ppb copper or less, to levels approaching the SBPS of 5.6 ppb copper (at 40 ppm hardness), also require protocols that have detection limits of 0.5 ppb copper and 2 ppb zinc. These protocols require a high level of QA/QC and longer analytical turn-around time than other less rigorous analytical methods.
- Analytical accuracy for surface water samples with very low metal levels may itself be a significant uncertainty in assuring efficient SCDD release operations to comply with the SBPS. For example an analytical error of 0.5 to 1.0 ppb copper in the clean water dilution flows that dominate the Keswick Reservoir water balance is itself 8.9 to 17.8 percent of the SBPS for copper (5.6; hardness = 40 ppm).
- Analysis of Keswick Reservoir inflows and releases for hardness, alkalinity, TSS, TDS, pH, iron content and aluminum content are well within laboratory analytical capability and should be routine.
- Organic carbon, total suspended solids (TSS) or total dissolved solids (TDS) content may impact SCDD release operations, particularly related to accretion flows during storm periods. Because of the peak nature of the accretion flows, turn-around time would be critical in considering this factor in making SCDD operational decisions.

- Stratification of metals in the Spring Creek Reservoir may, at least at times, be a significant parameter in the operation of the SCDD releases. Because of the peak nature of the Spring Creek Reservoir inflows, turn-around time would be critical in considering Spring Creek Reservoir metal stratification in making SCDD operational decisions.

- Precipitation of metals in the Spring Creek arm of Keswick Reservoir (SCAKR) is a significant parameter in the operation of the SCDD releases. Because of the expected variability of conditions related to the precipitation of metals in SCAKR, turn-around time would be critical in considering metal precipitation in making SCDD operational decisions.

- Monitoring compliance with SBPS in receiving waters is a significant parameter in the operation of the SCDD releases. Because of the expected variability of conditions related to the metal fluctuations under highly variable storm conditions, turn-around time would be critical in making SCDD operational decisions.

The Keswick Reservoir Mass Balance Approach for the Calculation of Allowable SCDD Release Rates

In determining the maximum safe level of release of IMM heavy metal contaminated waters stored in Spring Creek Reservoir, EPA employs a mass balance approach to calculate the allowable SCDD discharge that would assure meeting the protective State Basin Plan Standards (SBPS) in the Sacramento River.

Keswick Reservoir and the CVP facilities that provide inflows and releases are shown in Figure 1. They include releases from Shasta Dam, the Spring Creek Power House (SCPH), the Spring Creek Debris Dam (SCDD) outlet and Keswick Dam. Storm water runoff and other inflow ("accretion flow") that drain the area adjacent to Keswick Reservoir provide an additional flow component and metal load.

The mass balance calculational approach depends upon the accurate estimation of the contribution of numerous Keswick Reservoir inflows and the Keswick Dam releases both in terms of flow volume and metal concentrations. Under this approach the amounts of dissolved copper and zinc entering Keswick Reservoir (from sources other than the IMM heavy metal contaminated waters of the Spring Creek watershed that comprise the SCDD releases), and the amounts of dissolved copper and zinc that would be allowed to leave the reservoir while meeting the protective SBPS are estimated. By comparing these estimates, and taking into consideration the amount of copper and zinc that would be expected to precipitate out of solution as particulate matter in Keswick Reservoir, the allowable SCDD copper and zinc release can be calculated. The allowable volume of the SCDD outlet release is then determined based upon the characteristics of the waters stored in Spring Creek Reservoir. Figure 2 provides a flow chart for the IMM WQM that depicts these Keswick Reservoir inflows and releases in a schematic format.

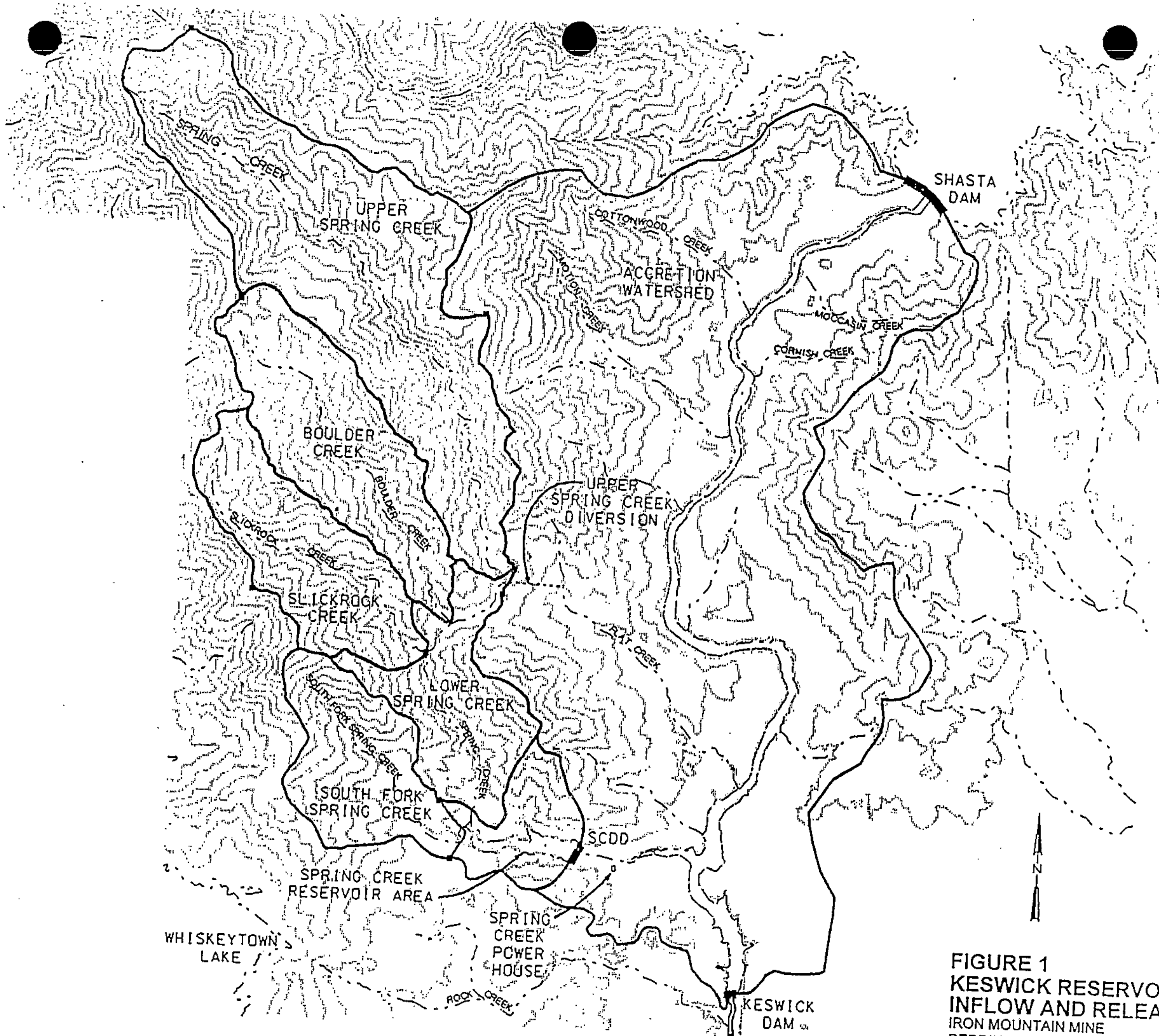

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FIGURE 1
KESWICK RESERVOIR INFLOW AND RELEASES
IRON MOUNTAIN MINE
REDDING, CALIFORNIA

The important metal loads and flow components of the Keswick Reservoir mass balance under controlled release conditions (i.e. no AMD spills from the SCDD) include releases from Shasta Dam, the Spring Creek Power House (SCPH), the Spring Creek Debris Dam (SCDD) outlet and Keswick Dam. Storm water runoff and other inflow ("accretion flow") that drain the area adjacent to Keswick Reservoir provide an additional flow component and metal load. The key characteristics of the Keswick Reservoir inflows and Keswick Dam releases are listed in Table 1. These flows are described in the following sections and more fully in Appendix B.

TABLE 1

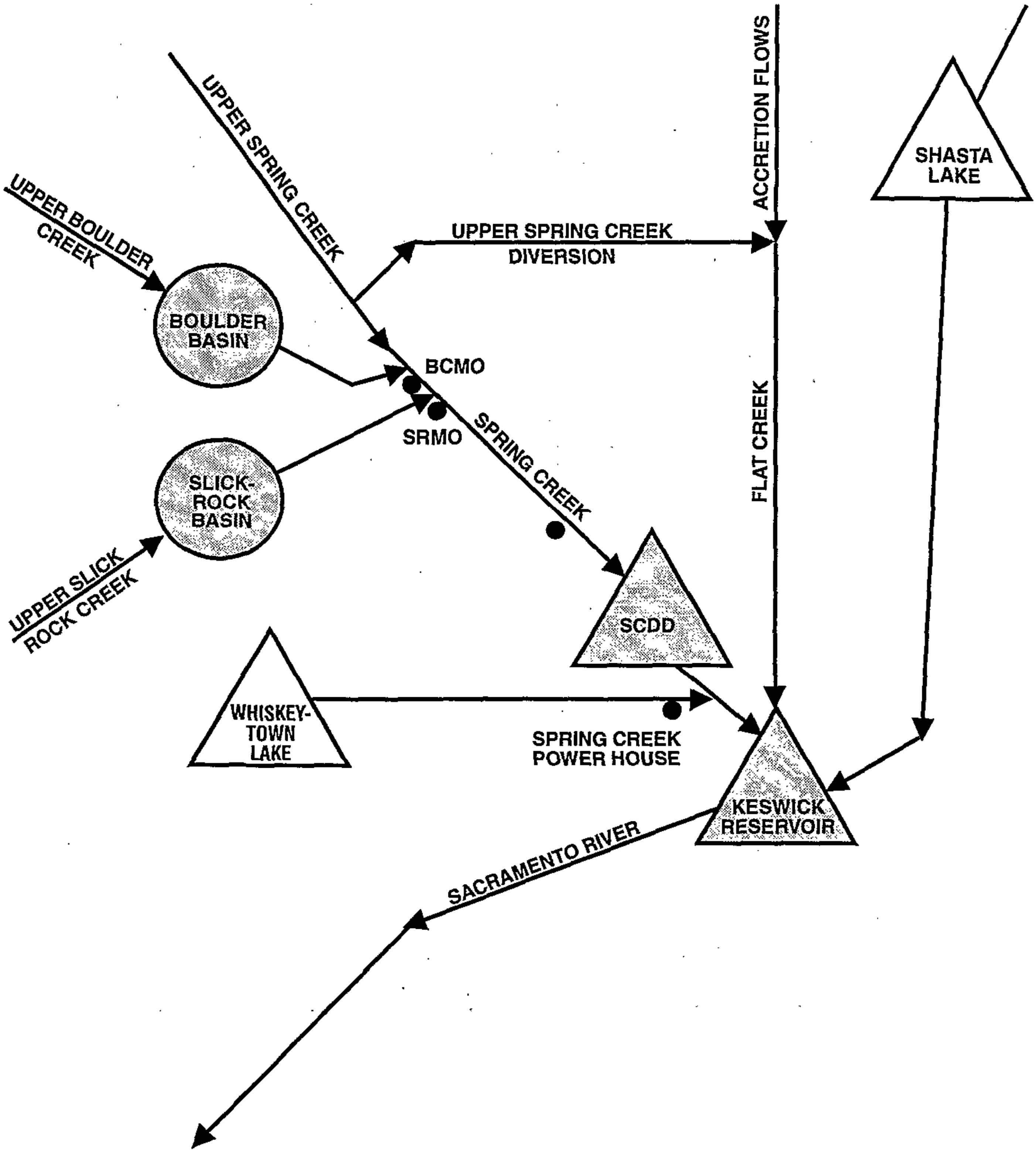
Keswick Reservoir Inflow and Release Characteristics

SCDD Operation Efficiency

Inflows and Releases	Key Characteristics
Shasta Dam	Moderate to very high flow volume (generally 3,000 to as high as 80,000 cfs).
	Copper concentrations are very low (1 to 2 ppb).
	Release support peak power production except under very high flow releases. Keswick Dam is operated to store or release these flows for regulation of the Sacramento River.
Spring Creek Powerhouse	Low to moderate flow volume (50 to 4,000 cfs).
	Copper concentrations are very low (near 1 ppb).
	Releases generally support peak power production. Keswick Dam is operated to store or release these flows for regulation of the Sacramento River.
Keswick Reservoir Accretion Flows	Low to moderate flow volume (500 to 7,000 cfs).
	Low copper concentration (generally 3 to 6 ppb).
	Peak flow characteristics. Keswick Dam is operated to store or release these flows for regulation of the Sacramento River.
Keswick Dam	Moderate to very high flow volume (generally 3,000 to as high as 80,000 cfs).
	Copper concentrations are low (2 to 6 ppb) except during AMD spills (generally 6 to 14 ppb).
	Releases regulate the Sacramento River flow and provide baseload power production.
Spring Creek Debris Dam Outlet	Low to moderate flow volume (no release to 800 cfs).
	Very high copper concentrations (200 to 1,000 ppb).

Shasta Dam Releases

- Shasta Dam releases generally provide the dominant flow component of the Sacramento River and the Keswick Reservoir water balance.



2296_01

FIGURE 2
FLOWCHART SCHEMATIC

- The Shasta Dam releases are relied on to provide dilution of the SCDD releases that are highly contaminated by acid mine drainage discharges from IMM. Copper and zinc are present in the Shasta Dam release in low to very low concentration levels.

- Shasta Dam release water quality is an important factor with respect to managing SCDD releases of IMM metals under controlled release conditions.

Issues

- Accurate Shasta Dam release rate flow information is required to successfully manage a potential remedial action that would depend on these flows to safely dilute IMM AMD metal discharge loads.

- Bi-hourly CVP operations data indicate significant variability in the Shasta Dam release when the Shasta Dam power house is operated to produce peak power.

- Shasta Dam release peak discharges are stored in Keswick Reservoir and released into the Sacramento River to regulate river flow. The storage and later release of these waters impacts the physical availability of waters in the lower third of Keswick Reservoir to assure dilution of the IMM contaminant inflows.

- Daily average Shasta Dam release flow rates could be considered as adequate input to *the Keswick Reservoir mass balance. However, uncertainty is introduced except during* periods when CVP operations are stable over the course of the day such as during periods of flood control release operations or during periods in which the Shasta Dam power house is operating to produce "base load" power.

- The USBR operational summary is currently maintained for USBR record keeping and operational decision making requirements. Future reliance on such an operational record for engineering data to be input into the Keswick Reservoir mass balance requires that the accuracy and precision of the operational record to be assured through quality control and quality assurance procedures for the record keeping.

- Although Shasta Lake is a large reservoir, the water quality in the Shasta Dam releases can vary due to storm water inflows. The size of the reservoir reduces the observed variability, which has been from concentrations of less than 1 ppb to approximately 2 ppb of dissolved copper. An error of 1 ppb in the reported Shasta Dam release copper concentration, at a time when the Shasta Dam release is the dominant dilution flow, would result in an approximate 12 percent error in the calculation of the allowable SCDD release (assumes controlled release conditions; copper precipitation rate of 35 percent; SBPS = 5.6 @ 40 ppm hardness).

- Analytical capability to accurately measure metal concentrations at the levels present in Shasta Dam releases requires a very high level of quality assurance.

Whiskeytown Lake/SCPH Release

- The SCPH releases can at times provide the dominant flow component of the Sacramento River and the Keswick Reservoir water balance.

- The SCPH releases are relied on to provide dilution of the SCDD releases that are highly contaminated by acid mine drainage discharges from IMM. Copper and zinc are present in the SCPH releases in low to very low concentration levels.

Issues

- Accurate SCPH release rate flow information is required to successfully manage a potential remedial action that would depend on these flows to safely dilute IMM AMD metal discharge loads.

- Bi-hourly CVP operations data indicate significant variability in the SCPH release because it is generally relied on to produce peak power.

- Variability in the SCPH discharges impacts the physical and chemical processes that occur in the Spring Creek arm of Keswick Reservoir (SCAKR) as the IMM metal discharges are diluted and then transported into Keswick Reservoir and the Sacramento River.

- SCPH releases are stored in Keswick Reservoir and released into the Sacramento River to regulate river flow. The storage and later release of these waters impacts the physical availability of waters in the lower third of Keswick Reservoir to assure dilution of the IMM contaminant inflows.

- The USBR operational summary is currently maintained for USBR record keeping and operational decision making requirements. Future reliance on such an operational record for engineering data to be input into the Keswick Reservoir mass balance requires that the accuracy and precision of the operational record to be assured through quality control and quality assurance procedures for the record keeping.

- The potential for variability in water quality of the SCPH releases appears to be low.

- Analytical capability to accurately measure metal concentrations at the levels present in SCPH releases requires a very high level of quality assurance and quality control.

Keswick Reservoir Accretion Flows

- Keswick Reservoir Accretion flows, or storm water inflows to Keswick Reservoir, are characterized by the peak nature of the inflows.

- During periods when the accretion flows provide the primary component of the Keswick Reservoir water balance, these accretion flows also provide a significant metal input to the mass balance for Keswick Reservoir. The accretion flows have varying copper concentrations that range from values that are very low to values that are at or near the protective SBPS concentrations.

- Accretion flows can be estimated from CVP operations reports regarding SCDD inflows and an area apportionment approach.

- The available data set that can be relied on to characterize the water quality of the Keswick Reservoir accretion flows is limited. To date it has been necessary to assume an average concentration for these flows based on the available data.

- Data from the storm of 1995 support the conclusion that accretion flows generally are waters with low hardness that can significantly reduce the overall hardness of the Sacramento River during storms.

- Accretion flows may at times be a significant source of suspended particulate matter. The high levels of particulates may contribute to increase metal precipitation rates through an adsorption process.

Issues

- Accurate Keswick Reservoir accretion flow rate information is required to successfully manage a potential remedial action that would depend on these flows to safely dilute IMM AMD metal discharge loads.

- Bi-hourly CVP operations data could be relied on to calculate accretion flows either by: relying on the SCR inflows; or 2) by difference from all other known inflows and the change in storage. However, uncertainty is introduced by the limitations on the accuracy of this approach.

- Accretion flows are stored in Keswick Reservoir and released into the Sacramento River to regulate river flow. The storage and later release of these waters impacts the physical availability of waters in the lower third of Keswick Reservoir to assure dilution of the IMM contaminant inflows.

- EPA's 1995-1996 water year sampling efforts have established that the Keswick Reservoir accretion flows contained significant levels of metals (area weighted average of 4.3 ppb dissolved copper and 19.4 ppb dissolved zinc. These reported metal concentrations would limit the use of the Keswick Reservoir accretion flows for dilution of IMM metal discharges.

Keswick Dam Release

- USBR CVP operations information can be relied upon to accurately estimate these high volume Keswick Dam releases. Because Keswick Dam releases are relied upon to regulate the flow of the Sacramento River, these releases are the most stable of the releases from CVP facilities in the Keswick Reservoir system.

- In the future, after implementation of EPA's remedy for the IMM heavy metal discharges, controlled release operations are expected to be able to assure attainment of these protective SBPS.

- There is some uncertainty with respect to characterization of the quality of these waters. In general, it can be difficult to assure the representativeness of water quality samples taken below Keswick Dam (particularly during storm periods with high accretion flows).

Issues

- The measurement and uncertainty associated with the Keswick Dam release rates is an extremely important factor for the performance of the Keswick Reservoir mass balance.

- The USBR reported Keswick Dam releases are generally considered to be reliable daily average values. The USBR maintains stable Keswick Dam release rates in order to meet requirements for river regulation.

- The USBR operational summary is currently maintained for USBR record keeping and operational decision making requirements. Future reliance on such an operational record for engineering data to be input into the Keswick Reservoir mass balance requires that the accuracy and precision of the operational record to be assured through quality control and quality assurance procedures for the record keeping.

- The measurement and reporting uncertainty associated with the Keswick Dam release water quality is an extremely important factor for the overall Keswick Reservoir mass balance.

- There is uncertainty whether the sampling location beneath Keswick Dam allows for taking representative dissolved copper and zinc concentrations experienced in the Sacramento River. During storms, side-flow may dilute the Sacramento River waters at the point at which it is being sampled.

- EPA's sensitivity analyses show that a 1 ppb difference in the reported water quality at this station could result in a significant difference in the calculated allowable SCDD release under certain situations.

- Acquiring hourly data to define conditions in the Sacramento River during storm events is technically feasible; but would be costly. Because this station is important for efficient operations frequent monitoring may be necessary.

- Analytical capability to accurately measure metal concentrations at the levels present in Keswick Dam releases requires a very high level of quality assurance.

SCDD Outlet Release

- The SCDD outlet release is the primary controlled variable in operations of CVP facilities at Keswick Reservoir to assure dilution of the IMM contaminant discharges to safe levels. The Keswick Reservoir mass balance is performed to calculate the allowable SCDD outlet release rate.

- The SCDD releases, which contain the IMM metal discharges, are generally the most significant metal input of the Keswick Reservoir mass balance.

- Release rates from the SCDD outlet works can be accurately measured.

- The water quality of these concentrated metal discharges can readily be monitored, but vary significantly during storm inflows to the Spring Creek Reservoir.

Issues

- Measurement and reporting uncertainty associated with the SCDD Outlet release rates is a very significant factor for the overall Keswick Reservoir mass balance for all storm periods. The metal loads from the SCDD outlet releases dominate the Keswick Reservoir mass balance during this period. Any reporting or measurement error would significantly alter the calculated mass balance and metal precipitation rates.

- Flow rates for the outlet weir can be reliably measured.

- The bi-hourly operations data provide a detailed record of SCDD outlet release operations for those circumstances during which operational changes are made more frequently than daily.

- The USBR operational summary is currently maintained for USBR record keeping and operational decision making requirements. Future reliance on such an operational record for engineering data to be input into the Keswick Reservoir mass balance requires that the accuracy and precision of the operational record to be assured through quality control and quality assurance procedures for the record keeping.

- The water quality of these concentrated metal discharges can readily be monitored, but varies significantly during storm inflows to the Spring Creek Reservoir.

Coordination of SCDD with CVP Facilities

Water quality problems caused by the discharge of acid mine drainage from Spring Creek into Keswick Reservoir and the Sacramento River are a major concern to CVP operations. The CVP Operation Criteria and Plan (OCAP) includes a section dedicated to the special considerations that current USBR operations take into account in administering Shasta Division facilities.

During the wetter months, operating the SCDD to meet target reservoir elevations and Sacramento River water quality objectives is difficult and requires increased attention and exercise of discretion. As required by interim and final remedies for the IMM heavy metal discharges that would rely, in part, on water management actions involving SCDD operations, a mass balance approach would be employed to calculate the maximum safe level of release of IMM heavy metal contaminated waters stored in Spring Creek Reservoir that would assure meeting the protective SBPS in the Sacramento River. The allowable SCDD release decision would be made in coordination with USBR decision making regarding operations of all interrelated CVP facilities.

The management of the release of waters from CVP facilities is a complex task. The management of CVP facilities is governed by a series of federal laws, regulations, directives, water rights, contracts and agreements. In addition to limitations imposed by law, there are significant physical constraints on the operation of the CVP. Each facility has unique physical characteristics (such as size, storage capacity, spillway design and structure, among other things) and each has a different watershed area that varies geographically. For example, precipitation and runoff in each watershed can vary significantly in intensity, duration and timing. These legal and physical constraints are considered when making operational decisions.

The mass balance calculational approach for determining the allowable SCDD release, in the context of all related Shasta Division operations, depends upon the accurate estimation of CVP facility releases, Keswick Reservoir accretion inflows and the Keswick Dam releases, both in terms of flow volume and metal concentrations. Under this approach, the amounts of dissolved copper and zinc entering Keswick Reservoir (from sources other than the IMM heavy metal contaminated waters of the Spring Creek watershed that comprise the SCDD releases), and the amounts of dissolved copper and zinc that would be allowed to leave the reservoir while meeting the protective SBPS are estimated. By comparing these estimates, and taking into consideration the amount of copper and zinc that would be expected to precipitate out of solution as particulate matter in Keswick Reservoir, the allowable SCDD copper and zinc release can be calculated for a set of CVP operational conditions.

The allowable volume of the SCDD outlet release is then determined based upon the characteristics of the waters stored in Spring Creek Reservoir and the need for any adjustment to CVP operational parameters.

Objectives

The objectives of CVP decision making to support SCDD operational decision making are to:

- Assess the system-wide response of watersheds to the storm event; asses the impact of system-wide watershed responses on CVP facility operations; and asses the need to make modifications to CVP facility operations in response to the progress of the storm event

- In the context of CVP operational decision making, assess the need for modification to SCDD release operations based upon evaluation of the data, data uncertainty and the results of the mass balance calculation

Key Tasks

- USBR monitors CVP operations 24-hours per day at Sacramento and at Keswick Dam. Water operations personnel are always available on call. The operations required to run the SCDD are complex, and yet the factors described below must be integrated into the operation of the northern CVP, an even more complex system:

- USBR monitors water data (including inflow, release, elevation and storage). Data is retrievable from the CVP operations system on a 6-minute interval basis. Water data is stored on a bi-hourly basis for Spring Creek Reservoir, Whiskeytown Reservoir, Keswick Reservoir and Shasta Reservoir.

- USBR monitors real time precipitation data in the vicinity of the Spring Creek watershed at Redding, Shasta Dam, Brandy Creek and Clear Creek.

- USBR monitors surface water flows, available on an hourly basis via the California Data Exchange (CDEC) for Cottonwood Creek, Cow Creek, Battle Creek and Bend Bridge.

- USBR reviews available weather forecasting from the National Weather Service, radar images and satellite images. USBR prepares quantitative precipitation forecasts and inflow forecasts during significant events for Shasta Reservoir.

- The USBR coordinates its SCDD operations with the California Department of Fish and Game and the U.S. fish and Wildlife Service at times when the SCDD may spill AMD into the Sacramento River.

- USBR generally operates the SCPH and Shasta Dam power house to produce peak power.

- USBR coordinates changes in the regulated river flow with other agencies, providing a 2-hour notice period.

- Decisions to modify CVP operations with respect to Shasta Dam releases, Keswick Dam releases, SCPH releases and SCDD releases are made in Sacramento.

- USBR modifies operations at the SCDD remotely from Keswick Dam.

- USBR modifies operations of Shasta Dam releases, Keswick Dam releases and SCPH releases from Sacramento.

- USBR makes changes to the SCDD outlet louvers manually on-site. The SCDD has limited withdrawal capability from three levels of the reservoir.

- USBR acquires flow data from the SCDD weir manually.

The Declaration of Lowell Ploss, Operations Manager of the CVP, provides additional detail on the overarching requirements that govern the operations of the CVP, and is presented in Attachment C. The Declaration of Paul Fugitani, the hydraulic engineer responsible for CVP operations related to operation of the SCDD releases, provides additional detail on coordination of decision making regarding the SCDD outlet releases with other related CVP facilities, and is presented in Attachment D.

Issues

- The management of the release of waters from CVP facilities is a complex task that is governed by a series of federal laws, regulations, directives, water rights, contracts and agreements. CVP decision making, particularly during major storm events, is managed by State and federal employees from Sacramento on a system-wide basis, including all CVP and State Water Project facilities. Decision making to set the appropriate SCDD release must be made in the context of this complex system-wide analysis?

- In addition to limitations imposed by law, there are significant physical constraints on the operation of the CVP related to the unique physical characteristics (such as size, storage capacity, spillway design and structure, among other things) of each facility. Decision making to set the appropriate SCDD release must be made in the context of this analysis of the physical characteristics of individual CVP facilities.

- Each CVP facility has a different watershed area that varies geographically with varying precipitation and runoff characteristics in response to storm events. The response of each watershed varies in intensity, duration and timing of inflows. Decision making to set the appropriate SCDD release must be made in the context of this analysis of watershed response to unique storm events and impact on CVP facilities operations.

Operational Considerations

Once the decision has been made by the responsible USBR official that SCDD operation should be changed, that decision is communicated to operational personnel within the Shasta Division. Changes to SCDD operations can then readily be implemented. The changes must be verified by field inspection and flow measurement.

Objectives

The objectives of CVP operations with respect to managing SCDD releases are to:

- Efficiently implement operational modifications in a timely and accurate manner

- Verify that the changes have been properly made

Key Tasks

- Implement changes to the SCDD outlet works gate settings from the Keswick Dam operations office.

- Implement changes to the SCDD outlet works louver settings manually on-site.

- Verify that the gate settings have been properly made by observing the flow at the SCDD weir.

Issues

- Operational changes to implement modified SCDD release rates can readily be implemented at Keswick Dam but require verification to assure the accuracy of the change in settings. The potential for inaccurate settings is most likely: 1) at low release rates when a small change in the gate setting may significantly alter the release rate; and 2) during periods of high inflow when rapid filling of the SCR may sufficiently increase the flow through the gate because of increased head (potential energy).

- Verification of release rates currently requires an on-site inspection by field personnel. Correction of inaccurate settings would involve delay associated with the necessary site inspection.

- Change to settings of the SCDD outlet louvers for selective withdrawal requires the presence of personnel on-site at the SCDD to implement the change. Changes to louver settings would involve some time delay from notification of the need for a change to operations.

APPENDIX A

Storm Sampling Program to Support Spring Creek Debris Dam Operations

Analytical Services and Labor Cost Estimate

Operation of Spring Creek Debris Dam (SCDD) at high efficiency during storm periods to meet State Basin Plan standards (SBPS) in the Sacramento River requires timely collection and analysis of water quality and flow data collected at several locations around Keswick Reservoir. The selected sampling locations are sources of flow and metal loads to Keswick Reservoir. Three alternative sampling plans are presented here for collecting the necessary information to operate SCDD. Each alternative sampling plan provides differing capability to acquire data necessary to appreciably increase the efficiency of the SCDD with respect to acid mine drainage (AMD) releases. The plans differ in the frequency at which samples are collected.

Locations and Frequency

High Frequency Locations

The sampling locations and frequencies are listed in Table A-1 for the three plans. For each plan, the locations are separated into two groups based on the frequency of sampling. Samples are to be collected at five primary locations at the highest frequency. These locations are the most significant metal loads or flows to Keswick Reservoir during storm events. Collection of samples at Station 14 provides information regarding changes in concentrations in the influent to Spring Creek Reservoir (SCR) as the storm progresses. The Sacramento River below Keswick Reservoir is the sample point where samples are taken to assure complinace with the SBPS in the Sacramento River.

Low Frequency Locations

For each of the three plans, samples are collected at a lower frequency from nine additional locations. Samples collected at several depths in SCR provide information on the stratification of metal concentrations within the reservoir. This information is necessary to optimize releases from SCDD gates. Samples are to be collected at two locations in the Spring Creek arm of Keswick Reservoir (SCAKR) and at two locations in the main body of Keswick Reservoir (KR). These samples provide information regarding the extent of metal precipitation in the Reservoir as SCDD releases are mixed with releases from Spring Creek Powerhouse (SCPH) and Shasta Dam. Finally, samples are to be collected from three smaller drainages located between Keswick Dam and Shasta Dam on the west side of the Sacramento River. These drainages are Motion Creek, Flat Creek, and an unnamed drainage located west of Iron Mountain Mine Road approximately 0.4 mile north of SCDD. Based on data collected between December 1995 and March 1996 with the upper Spring Creek Diversion in operation, flows from these three drainages were sources of approximately 86 percent of the dissolved copper load and 90 percent of the dissolved zinc load in the numerous accretion flows between Shasta Dam and Keswick Dam.

Alternate Sample Frequency

For the five primary locations, the sample collection frequency ranges from one sample per hour to three samples per day for the three plans, as shown on Table A-1. For the nine additional locations, the sampling frequency ranges from three times per day to once daily.

TABLE A-1
Sampling Frequencies and Locations

Frequency	Plan 1	Plan 2	Plan 3	Locations
High	Hourly	Bi-hourly	Three times per day	SCDD release Station 14 SCPH Below Shasta Dam Below Keswick Dam
Low	Three times per day	Three times per day	Daily	Stratification samples on SCR. Two samples from SCAKR Two samples from the main body of KR Samples of three accretion flows

Analytes

The samples collected from the five primary locations at the highest frequency will be analyzed for total and dissolved copper and zinc. In addition, samples from Shasta Dam, SCPH, and below Keswick Dam will also be analyzed for hardness because the SBPS vary with hardness in the Sacramento River.

Three times a day for Sampling Plans 1 and 2 and once per day for Sampling Plan 3, all samples will be analyzed for total and dissolved copper, zinc, iron, and aluminum. Each of these metals precipitates to some extent as releases from SCDD mix with other flows in Keswick Reservoir. Additional analyses are performed for hardness, alkalinity, pH, total dissolved solids, total suspended solids, total organic carbon, and dissolved organic carbon.

Costs for each sampling plan are summarized on Table A-2. The sample locations, analytes, analytical costs, and labor costs for the three sampling plans are shown in detail on Tables A-3 through A-7. For each plan, it was assumed that one engineer would be working with several technicians on each shift. Total costs for the sampling plans range from $10,610 to $45,574 per day. Costs for improving access to Station 14 and costs for vehicle usage are not included.

TABLE A-2
Sampling Plan Costs

Sampling Frequency High/Low	Analytical Costs per Day	Labor Costs per Day	Total Costs per Day
Hourly/3 times per day	$ 35,375	$ 10,199	$ 45,574
Bi-hourly/3 times per day	$ 25,338	$ 7,800	$ 33,138
3 times per day/daily	$ 7,610	$ 3,000	$ 10,610

TABLE A-3
Sample Locations

Sample Location ID	Location
LSC	Spring Creek Debris Dam release
ST14	Station 14 on Spring Creek
SCR1	Spring Creek Reservoir stratification, depth 1
SCR2	Spring Creek Reservoir stratification, depth 2
WSKY	Spring Creek Powerhouse release
SCAKR1	Spring Creek arm of Keswick Reservoir, Location 1
SCAKR2	Spring Creek arm of Keswick Reservoir, Location 2
KR1	Keswick Reservoir, Location 1
KR2	Keswick Reservoir, Location 2
SRS	Shasta Dam release
ACC6	Mouth of Flat Creek (including flows from upper Spring Creek)
ACC15	Mouth of Motion Creek
ACC3	Unnamed drainage north of SCDD west of Iron Mountain Mine Road
SRK2	Sacramento River below Keswick Dam

TABLE A-4
Analytical Services Cost Estimate
Scenario 1: Hourly Sampling
Length of Storm (days): 1
Analytical Cost Multiplier[a] : 2

Sample Location ID	Samples per Day	Total Samples	Analytical Parameter	Unit Cost ($)	Subtotal Cost ($)	Subtotal Cost by Location
SCAKR1	3	3	Total Al, Cu, Fe, Zn	49.20	295.20	
	3	3	Dissolved Al, Cu, Fe, Zn	57.40	344.40	
	3	3	pH	8.20	49.20	
	3	3	Hardness	16.40	98.40	
	3	3	Alkalinity	16.40	98.40	
	3	3	TDS/TSS	32.80	196.80	
	3	3	TOC/DOC	65.60	393.60	
					Subtotal	$ 1,476.00

TABLE A-4
Analytical Services Cost Estimate
Scenario 1: Hourly Sampling
Length of Storm (days): 1
Analytical Cost Multiplier[a] : 2

Sample Location ID	Samples per Day	Total Samples	Analytical Parameter	Unit Cost ($)	Subtotal Cost ($)		Subtotal Cost by Location
SCAKR2	3	3	Total Al, Cu, Fe, Zn	49.20	295.20		
	3	3	Dissolved Al, Cu, Fe, Zn	57.40	344.40		
	3	3	pH	8.20	49.20		
	3	3	Hardness	16.40	98.40		
	3	3	Alkalinity	16.40	98.40		
	3	3	TDS/TSS	32.80	196.80		
	3	3	TOC/DOC	65.60	393.60		
					Subtotal	$	1,476.00
KR1	3	3	Total Al, Cu, Fe, Zn	49.20	295.20		
	3	3	Dissolved Al, Cu, Fe, Zn	57.40	344.40		
	3	3	pH	8.20	49.20		
	3	3	Hardness	16.40	98.40		
	3	3	Alkalinity	16.40	98.40		
	3	3	TDS/TSS	32.80	196.80		
	3	3	TOC/DOC	65.60	393.60		
					Subtotal	$	1,476.00
KR2	3	3	Total Al, Cu, Fe, Zn	49.20	295.20		
	3	3	Dissolved Al, Cu, Fe, Zn	57.40	344.40		
	3	3	pH	8.20	49.20		
	3	3	Hardness	16.40	98.40		
	3	3	Alkalinity	16.40	98.40		
	3	3	TDS/TSS	32.80	196.80		
	3	3	TOC/DOC	65.60	393.60		
					Subtotal	$	1,476.00
ACC3	3	3	Total Al, Cu, Fe, Zn	49.20	295.20		
	3	3	Dissolved Al, Cu, Fe, Zn	57.40	344.40		
	3	3	pH	8.20	49.20		
					Subtotal	$	688.80
ACC6	3	3	Total Al, Cu, Fe, Zn	49.20	295.20		
	3	3	Dissolved Al, Cu, Fe, Zn	57.40	344.40		
	3	3	pH	8.20	49.20		
					Subtotal	$	688.80
ACC15	3	3	Total Al, Cu, Fe, Zn	49.20	295.20		
	3	3	Dissolved Al, Cu, Fe, Zn	57.40	344.40		
	3	3	pH	8.20	49.20		
					Subtotal	$	688.80

TABLE A-4
Analytical Services Cost Estimate
Scenario 1: Hourly Sampling
Length of Storm (days): 1
Analytical Cost Multiplier[a] : 2

Sample Location ID	Samples per Day	Total Samples	Analytical Parameter	Unit Cost ($)	Subtotal Cost ($)	Subtotal Cost by Location
LSC	21	21	Total Cu, Zn	32.80	1,377.60	
	21	21	Dissolved Cu, Zn	41.00	1,722.00	
	3	3	Total Al, Cu, Fe, Zn	49.20	295.20	
	3	3	Dissolved Al, Cu, Fe, Zn	57.40	344.40	
	3	3	pH	8.20	49.20	
	3	3	TDS/TSS	32.80	196.80	
	3	3	TOC/DOC	65.60	393.60	
					Subtotal	$ 4,378.80
ST14	21	21	Total Cu, Zn	32.80	1,377.60	
	21	21	Dissolved Cu, Zn	41.00	1,722.00	
	3	3	Total Al, Cu, Fe, Zn	49.20	295.20	
	3	3	Dissolved Al, Cu, Fe, Zn	57.40	344.40	
	3	3	pH	8.20	49.20	
	3	3	TDS/TSS	32.80	196.80	
	3	3	TOC/DOC	65.60	393.60	
					Subtotal	$ 4,378.80
SCR1	3	3	Total Al, Cu, Fe, Zn	49.20	295.20	
	3	3	Dissolved Al, Cu, Fe, Zn	57.40	344.40	
	3	3	Hardness	16.40	98.40	
	3	3	Alkalinity	16.40	98.40	
	3	3	TDS/TSS	32.80	196.80	
	3	3	TOC/DOC	65.60	393.60	
					Subtotal	$ 1,426.80
SCR2	3	3	Total Al, Cu, Fe, Zn	49.20	295.20	
	3	3	Dissolved Al, Cu, Fe, Zn	57.40	344.40	
	3	3	Hardness	16.40	98.40	
	3	3	Alkalinity	16.40	98.40	
	3	3	TDS/TSS	32.80	196.80	
	3	3	TOC/DOC	65.60	393.60	
					Subtotal	$ 1,426.80
SRS	21	21	Total Cu, Zn	32.80	1,377.60	
	21	21	Dissolved Cu, Zn	41.00	1,722.00	
	21	21	Hardness	16.40	688.80	
	3	3	Total Al, Cu, Fe, Zn	49.20	295.20	
	3	3	Dissolved Al, Cu, Fe, Zn	57.40	344.40	
	3	3	pH	8.20	49.20	

TABLE A-4
Analytical Services Cost Estimate
Scenario 1: Hourly Sampling
Length of Storm (days): 1
Analytical Cost Multiplier[a] : 2

Sample Location ID	Samples per Day	Total Samples	Analytical Parameter	Unit Cost ($)	Subtotal Cost ($)		Subtotal Cost by Location
	3	3	Hardness	16.40	98.40		
	3	3	Alkalinity	16.40	98.40		
	3	3	TDS/TSS	32.80	196.80		
	3	3	TOC/DOC	65.60	393.60		
					Subtotal	$	5,264.40
WSKY	21	21	Total Cu, Zn	32.80	1,377.60		
	21	21	Dissolved Cu, Zn	41.00	1,722.00		
	21	21	Hardness	16.40	688.80		
	3	3	Total Al, Cu, Fe, Zn	49.20	295.20		
	3	3	Dissolved Al, Cu, Fe, Zn	57.40	344.40		
	3	3	pH	8.20	49.20		
	3	3	Hardness	16.40	98.40		
	3	3	Alkalinity	16.40	98.40		
	3	3	TDS/TSS	32.80	196.80		
	3	3	TOC/DOC	65.60	393.60		
					Subtotal	$	5,264.40
SRK2	21	21	Total Cu, Zn	32.80	1,377.60		
	21	21	Dissolved Cu, Zn	41.00	1,722.00		
	21	21	Hardness	16.40	688.80		
	3	3	Total Al, Cu, Fe, Zn	49.20	295.20		
	3	3	Dissolved Al, Cu, Fe, Zn	57.40	344.40		
	3	3	pH	8.20	49.20		
	3	3	Hardness	16.40	98.40		
	3	3	Alkalinity	16.40	98.40		
	3	3	TDS/TSS	32.80	196.80		
	3	3	TOC/DOC	65.60	393.60		
					Subtotal	$	5,264.40
					Total	**$**	**35,374.80**

[a] The analytical cost multiplier is used to estimate additional costs for rapid turn-around.

TABLE A-5
Analytical Services Cost Estimate
Scenario 2: Bi-Hourly Sampling
Length of Storm (days): 1
Analytical Cost Multiplier[a] : 2

Sample Location ID	Samples per Day	Total Samples	Analytical Parameter	Unit Cost ($)	Subtotal Cost ($)	Subtotal Cost by Location
SCAKR1	3	3	Total Al, Cu, Fe, Zn	49.20	295.20	
	3	3	Dissolved Al, Cu, Fe, Zn	57.40	344.40	
	3	3	pH	8.20	49.20	
	3	3	Hardness	16.40	98.40	
	3	3	Alkalinity	16.40	98.40	
	3	3	TDS/TSS	32.80	196.80	
	3	3	TOC/DOC	65.60	393.60	
					Subtotal	$ 1,476.00
SCAKR2	3	3	Total Al, Cu, Fe, Zn	49.20	295.20	
	3	3	Dissolved Al, Cu, Fe, Zn	57.40	344.40	
	3	3	pH	8.20	49.20	
	3	3	Hardness	16.40	98.40	
	3	3	Alkalinity	16.40	98.40	
	3	3	TDS/TSS	32.80	196.80	
	3	3	TOC/DOC	65.60	393.60	
					Subtotal	$ 1,476.00
KR1	3	3	Total Al, Cu, Fe, Zn	49.20	295.20	
	3	3	Dissolved Al, Cu, Fe, Zn	57.40	344.40	
	3	3	pH	8.20	49.20	
	3	3	Hardness	16.40	98.40	
	3	3	Alkalinity	16.40	98.40	
	3	3	TDS/TSS	32.80	196.80	
	3	3	TOC/DOC	65.60	393.60	
					Subtotal	$ 1,476.00
KR2	3	3	Total Al, Cu, Fe, Zn	49.20	295.20	
	3	3	Dissolved Al, Cu, Fe, Zn	57.40	344.40	
	3	3	pH	8.20	49.20	
	3	3	Hardness	16.40	98.40	
	3	3	Alkalinity	16.40	98.40	
	3	3	TDS/TSS	32.80	196.80	
	3	3	TOC/DOC	65.60	393.60	
					Subtotal	$ 1,476.00

TABLE A-5
Analytical Services Cost Estimate
Scenario 2: Bi-Hourly Sampling
Length of Storm (days): 1
Analytical Cost Multiplier[a] : 2

Sample Location ID	Samples per Day	Total Samples	Analytical Parameter	Unit Cost ($)	Subtotal Cost ($)	Subtotal Cost by Location
ACC3	3	3	Total Al, Cu, Fe, Zn	49.20	295.20	
	3	3	Dissolved Al, Cu, Fe, Zn	57.40	344.40	
	3	3	pH	8.20	49.20	
					Subtotal	$ 688.80
ACC6	3	3	Total Al, Cu, Fe, Zn	49.20	295.20	
	3	3	Dissolved Al, Cu, Fe, Zn	57.40	344.40	
	3	3	pH	8.20	49.20	
					Subtotal	$ 688.80
ACC15	3	3	Total Al, Cu, Fe, Zn	49.20	295.20	
	3	3	Dissolved Al, Cu, Fe, Zn	57.40	344.40	
	3	3	pH	8.20	49.20	
					Subtotal	$ 688.80
LSC	9	9	Total Cu, Zn	32.80	590.40	
	9	9	Dissolved Cu, Zn	41.00	738.00	
	3	3	Total Al, Cu, Fe, Zn	49.20	295.20	
	3	3	Dissolved Al, Cu, Fe, Zn	57.40	344.40	
	3	3	pH	8.20	49.20	
	3	3	TDS/TSS	32.80	196.80	
	3	3	TOC/DOC	65.60	393.60	
					Subtotal	$ 2,607.60
ST14	9	9	Total Cu, Zn	32.80	590.40	
	9	9	Dissolved Cu, Zn	41.00	738.00	
	3	3	Total Al, Cu, Fe, Zn	49.20	295.20	
	3	3	Dissolved Al, Cu, Fe, Zn	57.40	344.40	
	3	3	pH	8.20	49.20	
	3	3	TDS/TSS	32.80	196.80	
	3	3	TOC/DOC	65.60	393.60	
					Subtotal	$ 2,607.60
SCR1	3	3	Total Al, Cu, Fe, Zn	49.20	295.20	
	3	3	Dissolved Al, Cu, Fe, Zn	57.40	344.40	
	3	3	Hardness	16.40	98.40	
	3	3	Alkalinity	16.40	98.40	
	3	3	TDS/TSS	32.80	196.80	
	3	3	TOC/DOC	65.60	393.60	
					Subtotal	$ 1,426.80

TABLE A-5
Analytical Services Cost Estimate
Scenario 2: Bi-Hourly Sampling
Length of Storm (days): 1
Analytical Cost Multiplier[a] : 2

Sample Location ID	Samples per Day	Total Samples	Analytical Parameter	Unit Cost ($)	Subtotal Cost ($)		Subtotal Cost by Location
SCR2	3	3	Total Al, Cu, Fe, Zn	49.20	295.20		
	3	3	Dissolved Al, Cu, Fe, Zn	57.40	344.40		
	3	3	Hardness	16.40	98.40		
	3	3	Alkalinity	16.40	98.40		
	3	3	TDS/TSS	32.80	196.80		
	3	3	TOC/DOC	65.60	393.60		
					Subtotal	$	1,426.80
SRS	9	9	Total Cu, Zn	32.80	590.40		
	9	9	Dissolved Cu, Zn	41.00	738.00		
	9	9	Hardness	16.40	295.20		
	3	3	Total Al, Cu, Fe, Zn	49.20	295.20		
	3	3	Dissolved Al, Cu, Fe, Zn	57.40	344.40		
	3	3	pH	8.20	49.20		
	3	3	Hardness	16.40	98.40		
	3	3	Alkalinity	16.40	98.40		
	3	3	TDS/TSS	32.80	196.80		
	3	3	TOC/DOC	65.60	393.60		
					Subtotal	$	3,099.60
WSKY	9	9	Total Cu, Zn	32.80	590.40		
	9	9	Dissolved Cu, Zn	41.00	738.00		
	9	9	Hardness	16.40	295.20		
	3	3	Total Al, Cu, Fe, Zn	49.20	295.20		
	3	3	Dissolved Al, Cu, Fe, Zn	57.40	344.40		
	3	3	pH	8.20	49.20		
	3	3	Hardness	16.40	98.40		
	3	3	Alkalinity	16.40	98.40		
	3	3	TDS/TSS	32.80	196.80		
	3	3	TOC/DOC	65.60	393.60		
					Subtotal	$	3,099.60
SRK2	9	9	Total Cu, Zn	32.80	590.40		
	9	9	Dissolved Cu, Zn	41.00	738.00		
	9	9	Hardness	16.40	295.20		
	3	3	Total Al, Cu, Fe, Zn	49.20	295.20		
	3	3	Dissolved Al, Cu, Fe, Zn	57.40	344.40		
	3	3	pH	8.20	49.20		

TABLE A-5
Analytical Services Cost Estimate
Scenario 2: Bi-Hourly Sampling
Length of Storm (days): 1
Analytical Cost Multiplier[a] : 2

Sample Location ID	Samples per Day	Total Samples	Analytical Parameter	Unit Cost ($)	Subtotal Cost ($)	Subtotal Cost by Location
	3	3	Hardness	16.40	98.40	
	3	3	Alkalinity	16.40	98.40	
	3	3	TDS/TSS	32.80	196.80	
	3	3	TOC/DOC	65.60	393.60	
					Subtotal	$ 3,099.60
					Total	**$ 25,338.00**

[a] The analytical cost multiplier is used to estimate additional costs for rapid turn-around.

TABLE A-6
Analytical Services Cost Estimate
Scenario 1: Sampling Every 8 Hours
Length of Storm (days): 1
Analytical Cost Multiplier[a] : 2

Sample Location ID	Samples per Day	Total Samples	Analytical Parameter	Unit Cost ($)	Subtotal Cost ($)	Subtotal Cost by Location
SCAKR1	1	1	Total AL, Cu, Fe, Zn	49.20	98.40	
	1	1	Dissolved AL, Cu, Fe, Zn	57.40	114.80	
	1	1	pH	8.20	16.40	
	1	1	Hardness	16.40	32.80	
	1	1	Alkalinity	16.40	32.80	
	1	1	TDS/TSS	32.80	65.60	
	1	1	TOC/DOC	65.60	131.20	
					Subtotal	$ 492.00
SCAKR2	1	1	Total AL, Cu, Fe, Zn	49.20	98.40	
	1	1	Dissolved AL, Cu, Fe, Zn	57.40	114.80	
	1	1	pH	8.20	16.40	
	1	1	Hardness	16.40	32.80	
	1	1	Alkalinity	16.40	32.80	
	1	1	TDS/TSS	32.80	65.60	
	1	1	TOC/DOC	65.60	131.20	
					Subtotal	$ 492.00
KR1	1	1	Total AL, Cu, Fe, Zn	49.20	98.40	
	1	1	Dissolved AL, Cu, Fe, Zn	57.40	114.80	
	1	1	pH	8.20	16.40	
	1	1	Hardness	16.40	32.80	

TABLE A-6
Analytical Services Cost Estimate
Scenario 1: Sampling Every 8 Hours
Length of Storm (days): 1
Analytical Cost Multiplier[a] : 2

Sample Location ID	Samples per Day	Total Samples	Analytical Parameter	Unit Cost ($)	Subtotal Cost ($)	Subtotal Cost by Location
	1	1	Alkalinity	16.40	32.80	
	1	1	TDS/TSS	32.80	65.60	
	1	1	TOC/DOC	65.60	131.20	
					Subtotal	$ 492.00
KR2	1	1	Total AL, Cu, Fe, Zn	49.20	98.40	
	1	1	Dissolved AL, Cu, Fe, Zn	57.40	114.80	
	1	1	pH	8.20	16.40	
	1	1	Hardness	16.40	32.80	
	1	1	Alkalinity	16.40	32.80	
	1	1	TDS/TSS	32.80	65.60	
	1	1	TOC/DOC	65.60	131.20	
					Subtotal	$ 492.00
ACC3	1	1	Total AL, Cu, Fe, Zn	49.20	98.40	
	1	1	Dissolved AL, Cu, Fe, Zn	57.40	114.80	
	1	1	pH	8.20	16.40	
					Subtotal	$ 229.60
ACC6	1	1	Total AL, Cu, Fe, Zn	49.20	98.40	
	1	1	Dissolved AL, Cu, Fe, Zn	57.40	114.80	
	1	1	pH	8.20	16.40	
					Subtotal	$ 229.60
ACC15	1	1	Total AL, Cu, Fe, Zn	49.20	98.40	
	1	1	Dissolved AL, Cu, Fe, Zn	57.40	114.80	
	1	1	pH	8.20	16.40	
					Subtotal	$ 229.60
LSC	2	2	Total Cu, Zn	32.80	131.20	
	2	2	Dissolved Cu, Zn	41.00	164.00	
	1	1	Total AL, Cu, Fe, Zn	49.20	98.40	
	1	1	Dissolved AL, Cu, Fe, Zn	57.40	114.80	
	1	1	pH	8.20	16.40	
	1	1	TDS/TSS	32.80	65.60	
	1	1	TOC/DOC	65.60	131.20	
					Subtotal	$ 721.60
ST14	2	2	Total Cu, Zn	32.80	131.20	
	2	2	Dissolved Cu, Zn	41.00	164.00	
	1	1	Total AL, Cu, Fe, Zn	49.20	98.40	

TABLE A-6
Analytical Services Cost Estimate
Scenario 1: Sampling Every 8 Hours
Length of Storm (days): 1
Analytical Cost Multiplier[a] : 2

Sample Location ID	Samples per Day	Total Samples	Analytical Parameter	Unit Cost ($)	Subtotal Cost ($)	Subtotal Cost by Location
	1	1	Dissolved AL, Cu, Fe, Zn	57.40	114.80	
	1	1	pH	8.20	16.40	
	1	1	TDS/TSS	32.80	65.60	
	1	1	TOC/DOC	65.60	131.20	
					Subtotal	$ 721.60
SCR1	1	1	Total AL, Cu, Fe, Zn	49.20	98.40	
	1	1	Dissolved AL, Cu, Fe, Zn	57.40	114.80	
	1	1	Hardness	16.40	32.80	
	1	1	Alkalinity	16.40	32.80	
	1	1	TDS/TSS	32.80	65.60	
	1	1	TOC/DOC	65.60	131.20	
					Subtotal	$ 475.60
SCR2	1	1	Total AL, Cu, Fe, Zn	49.20	98.40	
	1	1	Dissolved AL, Cu, Fe, Zn	57.40	114.80	
	1	1	Hardness	16.40	32.80	
	1	1	Alkalinity	16.40	32.80	
	1	1	TDS/TSS	32.80	65.60	
	1	1	TOC/DOC	65.60	131.20	
					Subtotal	$ 475.60
SRS	2	2	Total Cu, Zn	32.80	131.20	
	2	2	Dissolved Cu, Zn	41.00	164.00	
	2	2	Hardness	16.40	65.60	
	1	1	Total AL, Cu, Fe, Zn	49.20	98.40	
	1	1	Dissolved AL, Cu, Fe, Zn	57.40	114.80	
	1	1	pH	8.20	16.40	
	1	1	Hardness	16.40	32.80	
	1	1	Alkalinity	16.40	32.80	
	1	1	TDS/TSS	32.80	65.60	
	1	1	TOC/DOC	65.60	131.20	
					Subtotal	$ 852.80
WSKY	2	2	Total Cu, Zn	32.80	131.20	
	2	2	Dissolved Cu, Zn	41.00	164.00	
	2	2	Hardness	16.40	65.60	
	1	1	Total AL, Cu, Fe, Zn	49.20	98.40	
	1	1	Dissolved AL, Cu, Fe, Zn	57.40	114.80	
	1	1	pH	8.20	16.40	

TABLE A-6
Analytical Services Cost Estimate
Scenario 1: Sampling Every 8 Hours
Length of Storm (days): 1
Analytical Cost Multiplier[a]: 2

Sample Location ID	Samples per Day	Total Samples	Analytical Parameter	Unit Cost ($)	Subtotal Cost ($)	Subtotal Cost by Location
	1	1	Hardness	16.40	32.80	
	1	1	Alkalinity	16.40	32.80	
	1	1	TDS/TSS	32.80	65.60	
	1	1	TOC/DOC	65.60	131.20	
					Subtotal	$ 852.80
SRK2	2	2	Total Cu, Zn	32.80	131.20	
	2	2	Dissolved Cu, Zn	41.00	164.00	
	2	2	Hardness	16.40	65.60	
	1	1	Total AL, Cu, Fe, Zn	49.20	98.40	
	1	1	Dissolved AL, Cu, Fe, Zn	57.40	114.80	
	1	1	pH	8.20	16.40	
	1	1	Hardness	16.40	32.80	
	1	1	Alkalinity	16.40	32.80	
	1	1	TDS/TSS	32.80	65.60	
	1	1	TOC/DOC	65.60	131.20	
					Subtotal	$ 852.80
					Total	**$ 7,609.60**

[a]The analytical cost multiplier is used to estimate additional costs for rapid turn-around.

TABLE A-7
Labor Cost Estimate

Scenario	Crews per Shift	People per Crew	Hours per Shift	Shifts per Day	Total Hours per Day	Average Cost per Hour*	Total Labor Cost
Hourly sampling	4	2	8	3	192	$53	$10,199
Bi-hourly sampling	3	2	8	3	144	$54	$7,800
3 times per day	1	2	8	3	48	$63	$3,000

*Assumes one engineer ($75/hour) working with technicians ($50/hour) on each shift.

APPENDIX B

Keswick Reservoir Inflow and Releases

Shasta Dam Releases

Shasta Dam releases are generally characterized as high to very high volume flows with low to very low copper concentrations.

Copper and zinc are present in the Shasta Dam release in low to very low concentration levels, well below the protective State Basin Plan standards (SBPS).

Shasta Dam releases generally provide the dominant flow component of the Sacramento River and the Keswick Reservoir water balance.

The Shasta Dam releases are relied on to provide dilution of the Spring Creek Debris Dam (SCDD) releases that are highly contaminated by acid mine drainage (AMD) discharges from Iron Mountain Mine (IMM).

At times the Shasta Dam release can provide a significant component of the overall Keswick Dam release copper and zinc loads.

For example, in cases where the protective SBPS for copper (5.6 ppb dissolved copper at a hardness of 40 ppm) are attained, and Shasta Dam is the sole source of clean water inflows to Keswick Reservoir (assuming 1.2 ppb of dissolved copper [see the Water Management Feasibility Study Addendum {WMFSA}, Appendix C, EPA, 1996]) relied on to dilute the IMM-contaminated SCDD releases, the copper load from the Shasta Dam releases would be approximately 21.4 percent of the overall copper load in the Keswick Reservoir inflows. In this example, 78.6 percent of the copper load would originate from the IMM contaminants in the SCDD releases.

There is some uncertainty with respect to characterization of the quality of these waters due to limitations of the accuracy of water quality analysis procedures at these low copper levels.

Shasta Dam Release Flow Rates

Shasta Dam release rates can be determined by (1) correlation with power production records, and (2) calculation based upon changes in Shasta Lake elevation and known operational settings.

Data Availability

Bi-hourly U.S. Bureau of Reclamation (USBR) operations data are not widely reported, but are available in an electronic database. The USBR has relied on this detailed record to make operational decisions regarding Keswick Reservoir Central Valley Project (CVP) facilities during past major storm events. The bi-hourly operations data indicate significant variability in the USBR Shasta Dam releases during periods when the Shasta Dam powerhouse operations are related to peak power production.

USBR CVP daily operations summary reports are much more widely available than the Bureau's bi-hourly data. The release rates reported by the USBR in its operations summary are values as of 12:00 midnight on the reporting day. These release rates provide information that can be relied upon to estimate the "daily average" flowrate of this high-volume Shasta Lake release. This approach is more reliable during periods of stable operation than during periods of operation for peak power production at Shasta Dam.

Characteristics

Figure B-1 depicts the Shasta Dam releases during the early January 1995 storm. The Shasta Dam powerhouse was operated throughout this storm period to produce peak power.

- The high degree of variability in the Shasta Dam releases during this period is typical of Shasta Dam release operations during early season storms.
- The peak discharges from Shasta Dam were regulated by Keswick Dam to maintain a stable flow regime in the Sacramento River.
- The regulated Shasta Dam releases were stored in Keswick Reservoir and only later released. This storage function of Keswick Reservoir complicates the analysis of the chemical and physical processes that would assure dilution of the IMM metal discharges to safe levels.
- The high degree of variability in the Shasta Dam releases would be expected to introduce significant variability in the metal concentrations observed below Keswick Dam.
- An accurate Keswick Reservoir storage and transport component to the IMM Water Quality Model (WQM) would be a difficult and complex model to develop and calibrate.

Figure B-2 compares the "daily average" Shasta Dam release to the "bi-hourly" release. Reliance on "daily average" values introduces significant uncertainty into the Keswick Reservoir mass balance during periods in which peak power production defines the Shasta Dam release.

Figure B-3 depicts the Shasta Dam releases during the March 1995 storm. The Shasta Dam releases were determined on the basis of flood control parameters during this late season storm period.

- The Shasta Dam releases during this period are typical of Shasta Dam release operations during a late season storm in which flood control parameters control the operations of Shasta Dam.
- The discharges from Shasta Dam were maintained throughout the day, or modified only occasionally, to maintain flood control storage capacity criteria in Shasta Lake.

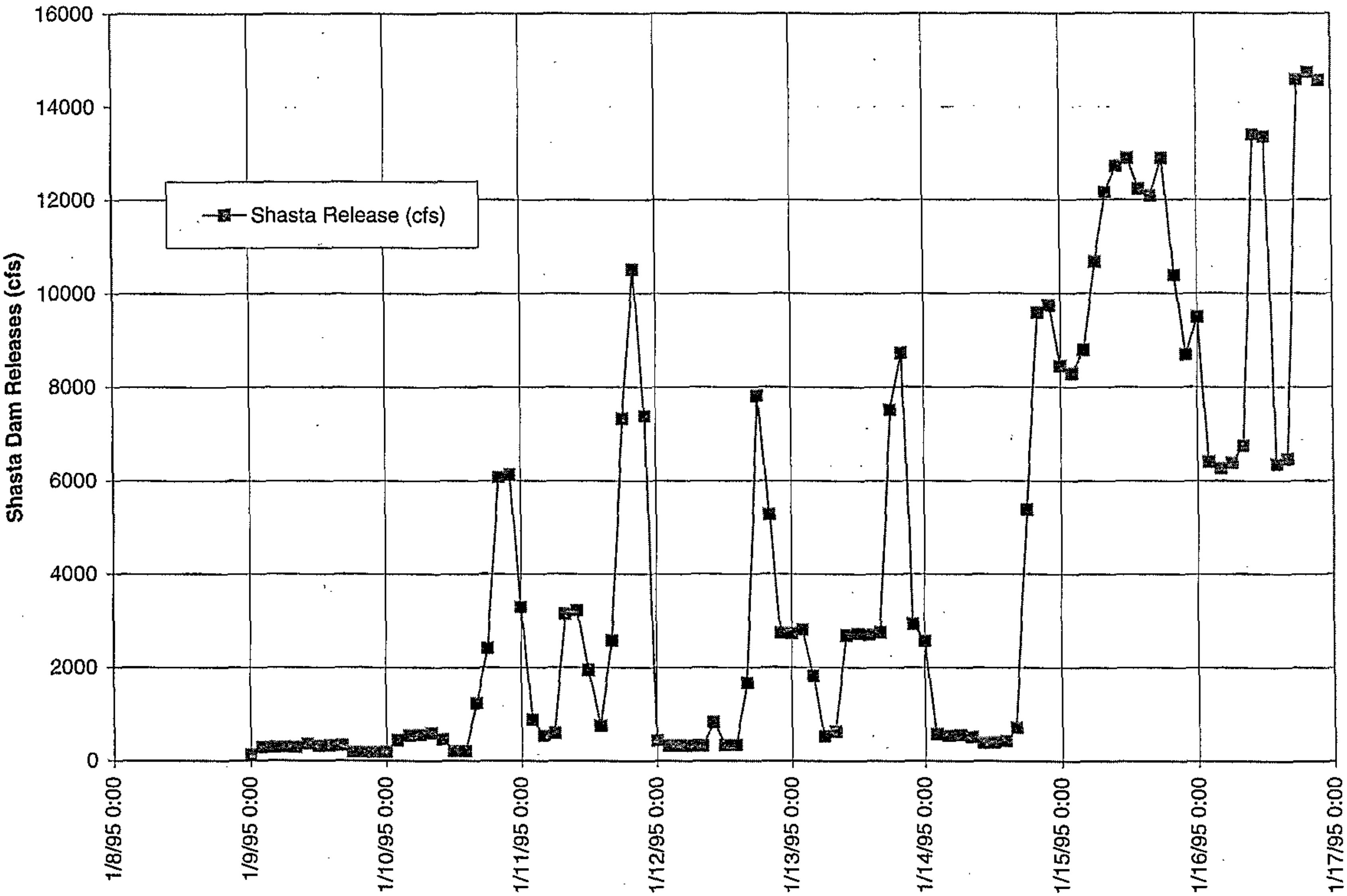


FIGURE B-1
SHASTA DAM RELEASES
IRON MOUNTAIN MINE, REDDING, CALIFORNIA

Early January 1995 Storm

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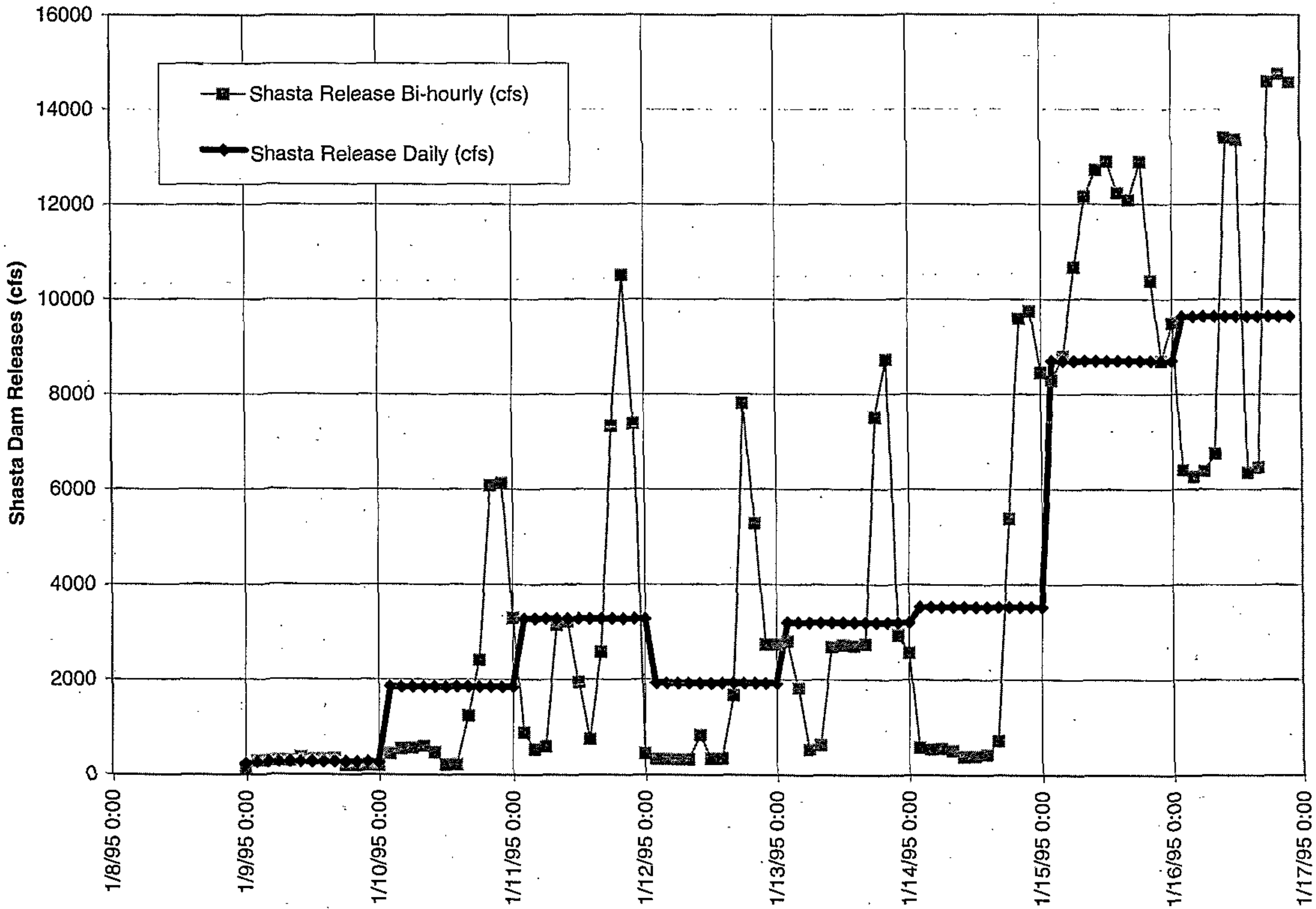

FIGURE B-2
SHASTA DAM RELEASES
IRON MOUNTAIN MINE, REDDING, CALIFORNIA

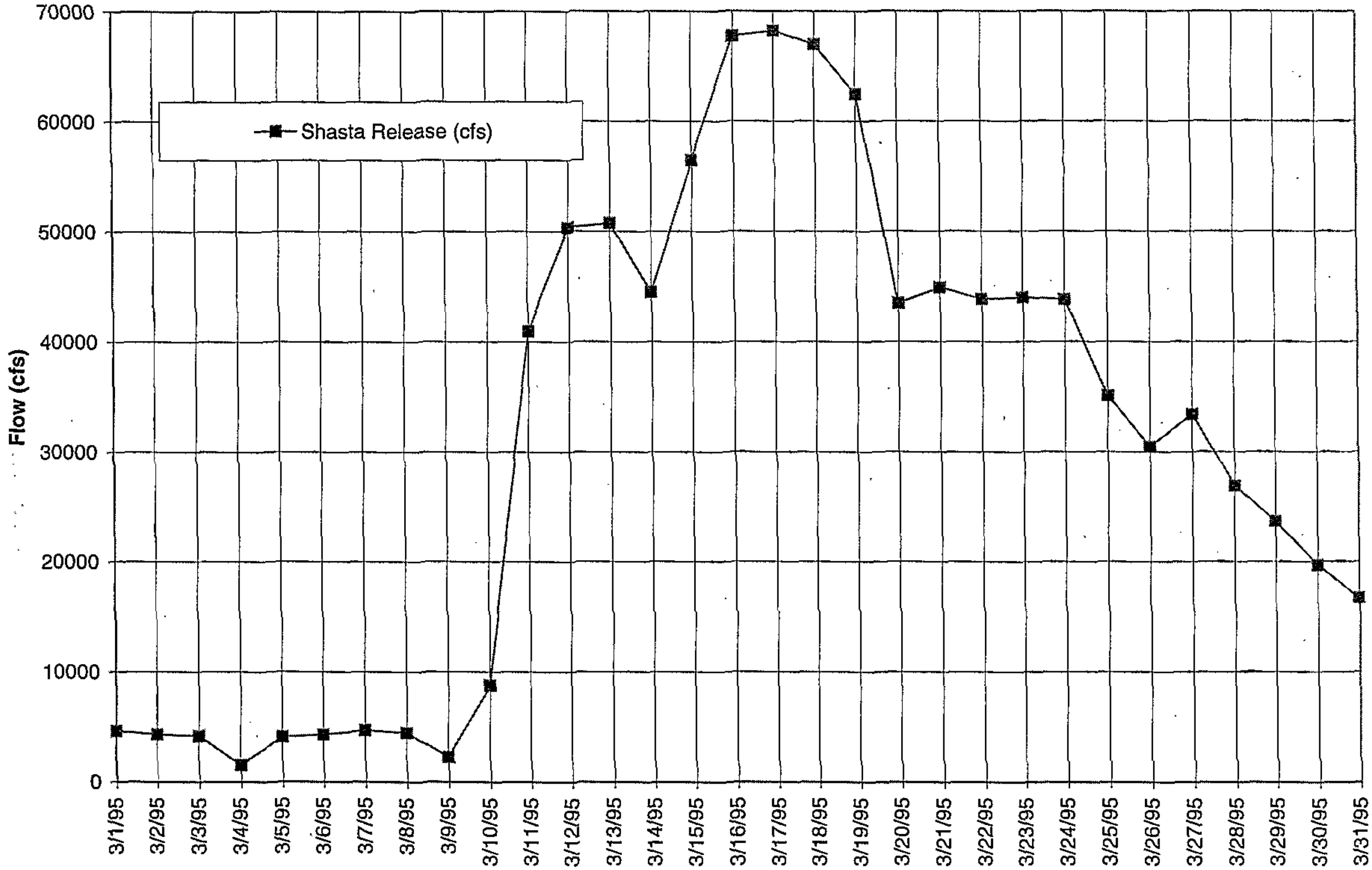

FIGURE B-3
SHASTA DAM RELEASE
IRON MOUNTAIN MINE, REDDING, CALIFORNIA

9/29/97
187appb4.xlsChart28

March 1995 Storm

- During this period the powerhouse would be expected to produce maximum power under base load conditions. Flows in excess of the powerhouse capacity were released from gated openings. Little flow variability would be expected over the course of a day of operation.

- The lack of variability in the Shasta Dam releases would be expected to reduce the level of uncertainty associated with SCDD operations to dilute the IMM metal discharges.

Figure B-4 compares the Shasta Dam releases during the March 1995 storm to the Keswick Dam releases. Keswick Reservoir was operated with essentially no storage component, in a run of the river mode.

Issues and Concerns

Accurate Shasta Dam release rate flow information is required to successfully manage a potential remedial action that would depend on these flows to safely dilute IMM AMD metal discharge loads.

Bi-hourly CVP operations data indicate significant variability in the Shasta Dam release when the Shasta Dam powerhouse is operated to produce peak power.

The release rates reported by the USBR in its operations summary are values as of 12:00 midnight on the reporting day. Operational parameters are often modified over the course of a day. The assumption that the reported values are reliable estimates for "daily average" release rates introduces some uncertainty into the mass balance calculation.

Daily average Shasta Dam release flowrates could be considered as adequate input to the Keswick Reservoir mass balance. However, uncertainty is introduced except during periods when CVP operations are stable over the course of the day such as during periods of flood control release operations or during periods in which the Shasta Dam powerhouse is operating to produce "base load" power.

Reliance on "daily average" values introduces significant uncertainty into the Keswick Reservoir mass balance during periods in which peak power production defines the Shasta Dam release. These peak discharges are stored in Keswick Reservoir and released into the Sacramento River to regulate river flow. The storage and later release of these waters impacts the physical availability of waters in the lower third of Keswick Reservoir to assure dilution of the IMM contaminant inflows.

The Shasta Dam release rates are directly related to power production up to the maximum powerhouse flowrates (approximately 12,000 cfs). The reported release rates are considered to be accurate flow measurements up to that flowrate.

For Shasta Dam release rates greater than the maximum powerhouse flowrates, releases are estimated for USBR operational purposes from powerhouse records, recorded lake elevations, and gate settings. The estimates of these high Shasta Dam release rates is less certain than the lower rates that can be reliably calculated from powerhouse operational records.

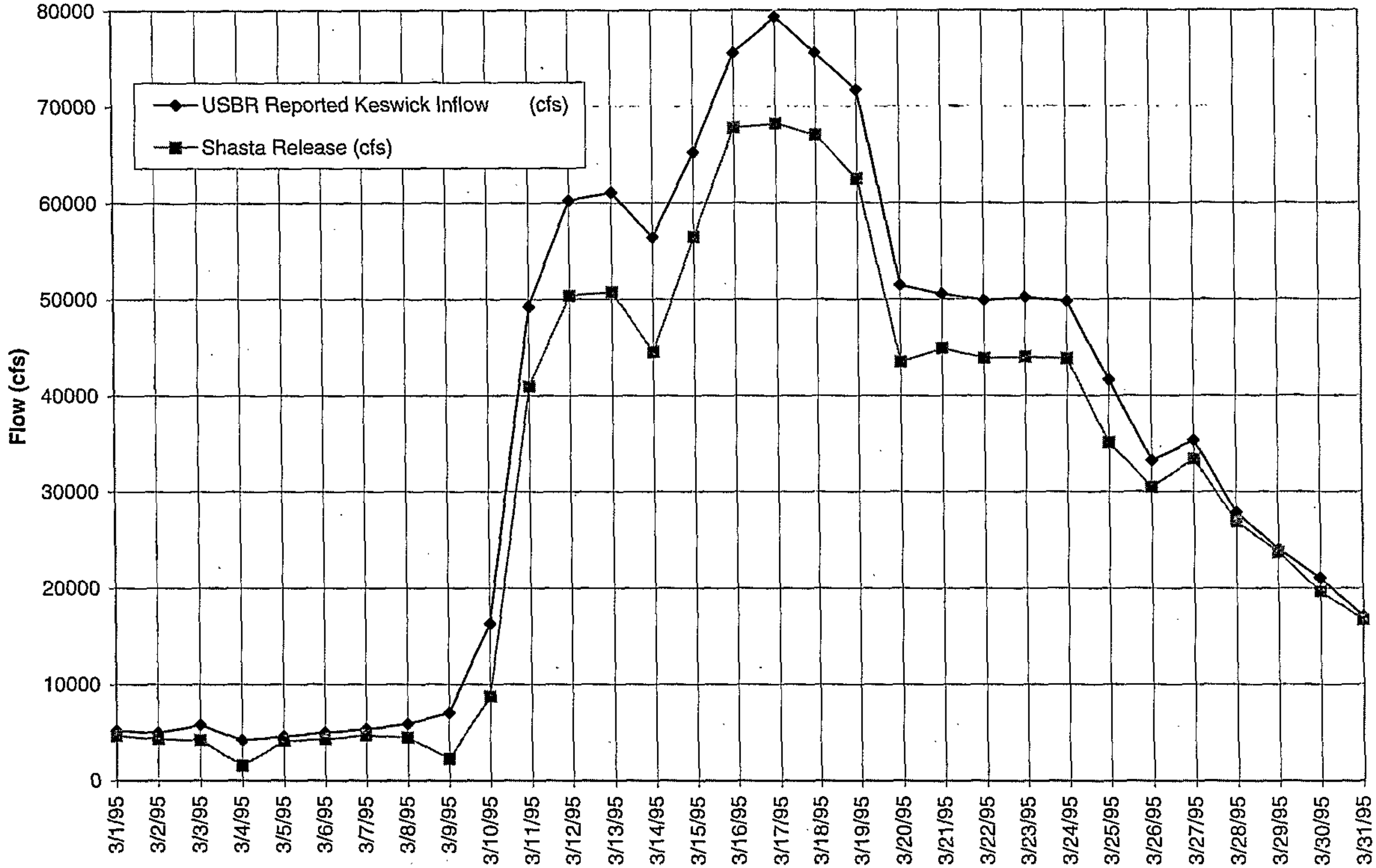

FIGURE B-4
KESWICK RESERVOIR INFLOWS AND SHASTA DAM RELEASES
IRON MOUNTAIN MINE, REDDING, CALIFORNIA

9/29/97
187appb4.xlsChart27

March 1995 Storm

The USBR operational summary is currently maintained for USBR record keeping and operational decision making requirements. It is not intended for use as engineering information of the sort needed for the performance of the Keswick Reservoir mass balance. Future reliance on such an operational record for engineering data to be input into the Keswick Reservoir mass balance requires that the accuracy and precision of the operational *record to be assured through stringent quality control and quality assurance procedures for* the record keeping focused on assuring the validity of the operational record for use as appropriate engineering data.

Shasta Dam Release Water Quality

Shasta Dam release water quality is an important factor with respect to managing SCDD releases of IMM metals under controlled release conditions.

The preferred approach would be to acquire "real time" water quality data to characterize the Shasta Dam releases. However, analytical techniques are not available to allow for "real time" analysis of copper, zinc, and hardness.

The second best approach would be to analyze a representative water quality sample as soon as practicable. However, the time delay associated with the performance of field sampling and the water quality analysis turn-around time is a significant factor in assuring "real time" water management operations to safely dilute the IMM metal discharges. Performing frequent sampling and expediting analysis of the sample would enhance operation efficiency. Frequent sampling and expediting analysis of the sample would significantly increase the associated cost.

The third best approach is to rely on a historic data set to characterize the Shasta Dam releases for operational purposes. This approach must rely on a conservative estimate of the average metal content for the mass balance calculation. Because significant variability occurs in each storm, depending on a wide range of factors, this approach is subject to some uncertainty.

The factors affecting the viability and reliability of each approach are discussed below.

Data Availability

The IMM data base contains dissolved copper and zinc data for the Shasta Dam discharges that have been acquired over the period of EPA's Superfund cleanup action. Historic data, largely acquired during an extended drought period, indicate that Shasta Dam releases averaged 2 ppb of copper. Data acquired during the recent wetter period, 1994 through 1996, indicate that the Shasta Dam copper releases average 1.2 ppb. (See the WMFSA, Volume II, Appendix C.4.2, EPA, 1996.)

The USBR currently acquires water quality data regarding the Shasta Dam release on a frequency of once or twice per week. The USBR has performed sampling as frequently as twice per day during past major storms and impending SCDD spill conditions.

However, the USBR does not currently report "dissolved" metal values. The USBR protocol specifies reporting "total soluble" metal concentrations (field acidification of the sample prior to filtering and analysis). This protocol is a conservative approach for managing reservoir operations that would provide a factor of safety to assure that "dissolved" metal concentrations would not exceed the protective SBPS.

The USBR has the capability to analyze the water quality samples locally. However, the reported detection limit for copper is currently 2 ppb. This detection limit is not adequate to accurately characterize the Shasta Dam releases for purposes of calculating mass balance. Analytical capability of measuring 0.5 ppb copper is required. The USBR may be able to upgrade its analytical capability or contract with a local laboratory for the required analytical support.

Issues and Concerns

Although Shasta Lake is a large reservoir, the water quality in the Shasta Dam releases can vary due to storm water inflows. The size of the reservoir reduces the observed variability, which has been observed to vary from concentrations of less than 1 ppb to approximately 2 ppb of dissolved copper.

On infrequent occasion, some other samples have reported concentrations of as high as 5 to 6 ppb of dissolved copper. However, it is uncertain whether these samples truly reflect a transitory condition or whether the analytical results were anomalous for some unexplained reason. Further sampling is required to study this issue.

There is significant uncertainty with respect to the practicability of analytical characterization of the quality of the Shasta Lake releases during "real time" CVP operations because of:

1. The potential for variability in water quality of the Shasta Dam releases, particularly during storm periods

2. The time required to perform field sampling and acquire a representative sample

3. The time required to perform the water quality analysis of the sample, quality assure the analysis and data, and report the water quality analysis results to operational personnel for consideration during operational decision making

4. The limitations of analytical procedures associated with measuring metal concentrations at these low to very low concentration levels

An alternate approach is to rely on the historic data set to define average Shasta Dam release metal concentrations, to be updated by additional monitoring performed on a less frequent schedule. Uncertainty, necessitating certain operational allowances, is introduced in this alternate approach by:

1. The potential for variability in water quality of the Shasta Dam releases, particularly during storm periods

2. The limitations of the historic data set (as updated) to adequately define the Shasta Lake release water quality under varying antecedent moisture and storm conditions

3. The analytical limitations associated with measuring metal concentrations at these low to very low concentration levels

Analytical capability to accurately measure metal concentrations at the levels present in Shasta Dam releases requires a very high level of quality assurance.

Documents in the IMM Administrative Record indicate that limitations inherent in current analytical techniques may produce results that are uncertain by as much as 0.2 to 0.3 ppb copper. Relative to the Shasta Dam releases, this may be as much as 10 to 30 percent of the actual sample value, but in comparison to the protective SBPS, this error would be approximately 3.6 to 5.4 percent. This analytical limitation introduces an additional small uncertainty into the mass balance analysis for these waters.

EPA has performed a sensitivity analysis to assess the many uncertainties involved in a Keswick Reservoir mass balance calculation. These analyses support the conclusion that data uncertainties are an important consideration in the interpretation of the mass balance results.

Whiskeytown Lake/Spring Creek Powerhouse Releases

Whiskeytown Lake/Spring Creek Power House (SCPH) releases are generally characterized as low to moderate volume releases with very low metal concentrations.

Copper and zinc are present in the SCPH releases in low to very low concentration levels.

The SCPH releases can at times provide the dominant flow component of the Sacramento River and the Keswick Reservoir water balance.

The SCPH releases are relied on to provide dilution of the SCDD releases that are highly contaminated by AMD discharges from IMM.

The associated copper load, present in low to very low concentration levels, is generally not a major component of the overall Keswick Dam release metal load. However, at times, the SCPH release can provide a significant component of the overall Keswick Dam release copper and zinc loads.

For example, in cases where the protective SBPS for copper (5.6 ppb dissolved copper at a hardness of 40 ppm) are attained, and SCPH release is the sole source of clean water inflows to Keswick Reservoir (assuming 1.3 ppb of dissolved copper [see the WMFSA, Appendix A, EPA, 1996]) relied on to dilute the IMM-contaminated SCDD releases, the copper load from the SCPH releases would be approximately 23.2 percent of the overall copper load in the Keswick Reservoir inflows. In this example, 76.8 percent of the copper load would originate from the IMM contaminants in the SCDD releases.

There is some uncertainty with respect to characterization of the quality of these waters because of limitations of the accuracy of water quality analysis procedures at these low copper levels.

SCPH Release Flow Rates

SCPH release rates are determined by correlation with power production records.

Data Availability

Bi-hourly USBR operations data are not widely reported, but are available in an electronic database. The USBR has relied on this detailed record to make operational decisions regarding Keswick Reservoir CVP facilities during past major storm events. The bi-hourly operations data indicate significant variability in the USBR SCPH releases during periods when the SCPH operations are related to peak power production.

USBR CVP daily operations summary reports are much more widely available than the Bureau's bi-hourly data. The release rates reported by the USBR in its operations summary are values as of 12:00 midnight on the reporting day. These release rates provide information that can be relied upon to estimate the "daily average" flowrate of the SCPH release. This reliability of this approach is uncertain.

Characteristics

Figure B-5 depicts the SCPH releases during the early January 1995 storm. The SCPH was operated throughout this storm period to produce peak power.

- The high degree of variability in the SCPH releases during this period is typical of SCPH release operations generally, including early season storms.
- The variable SCPH discharges intermixed with SCDD releases discharged at a constant rate, resulting in a varying dilution ratio and may have contributed to variable precipitation rates. (See EPA's 1996 laboratory and field precipitation studies, and the 1996 WMFSA, Volume II, Appendix E.)
- The SCPH discharges were regulated, in conjunction with the Shasta Dam releases, by Keswick Dam to maintain a stable flow regime in the Sacramento River.
- The regulated SCPH and Shasta Dam releases were stored in Keswick Reservoir and only later released. This storage function of Keswick Reservoir complicates the analysis of the chemical and physical processes that would assure dilution of the IMM metal discharges to safe levels.
- The high degree of variability in the Shasta Dam and SCPH releases during this period would be expected to introduce significant variability in the metal concentrations observed below Keswick Dam.
- An accurate Keswick Reservoir storage and transport component to the IMM WQM would be a difficult and complex model to develop and calibrate.

Figure B-6 compares the "daily average" SCPH release to the "bi-hourly" release during the early January 1995 storm. This figure indicates that reliance on "daily average" values introduces significant uncertainty into the Keswick Reservoir mass balance related to the SCPH releases.

Figure B-7 depicts the variability in the dissolved copper concentrations observed in the Sacramento River below Keswick Dam with the variability in the SCPH releases during the early January 1995 storm.

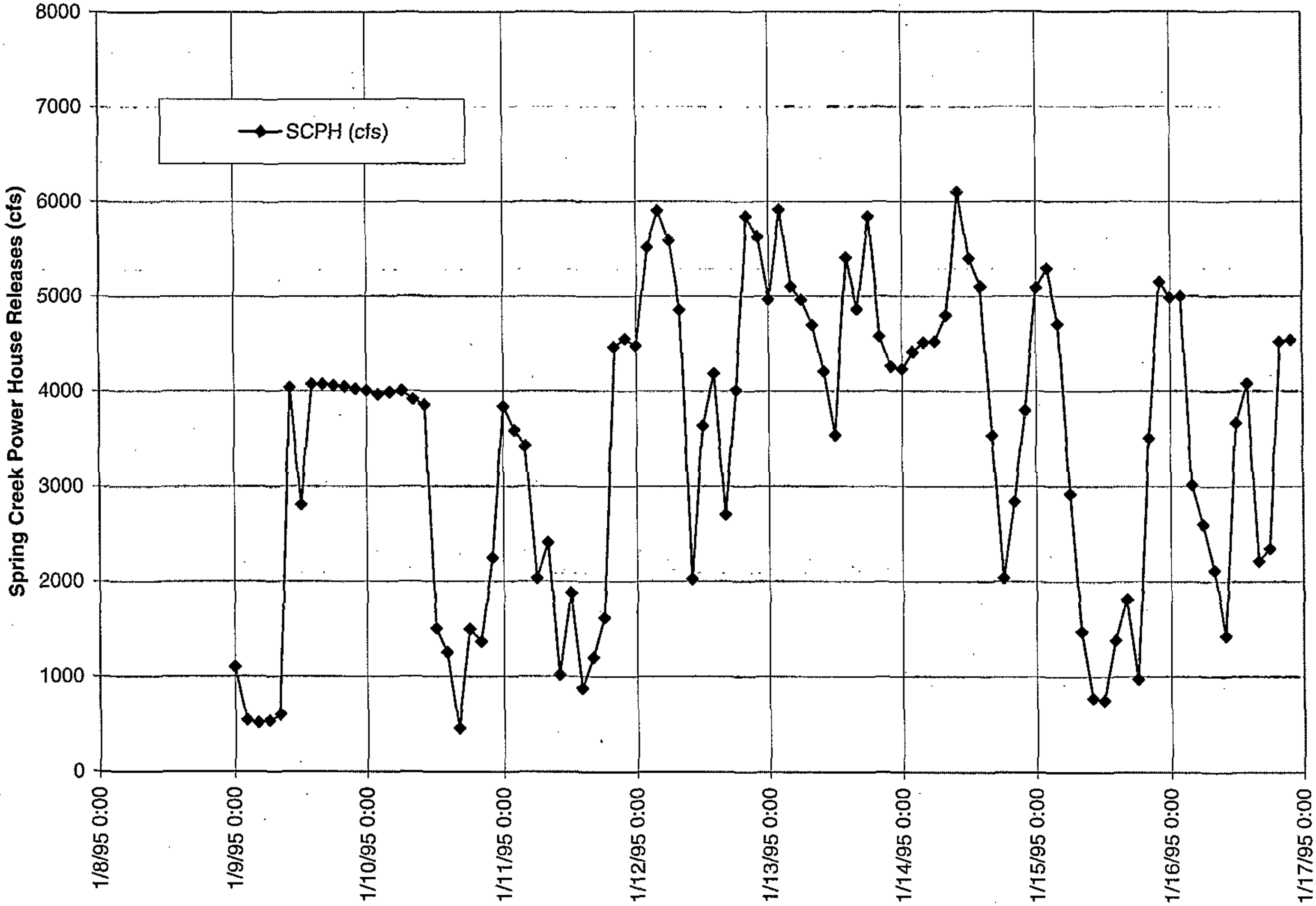

FIGURE B-5
SPRING CREEK POWER HOUSE RELEASES
IRON MOUNTAIN MINE, REDDING, CALIFORNIA

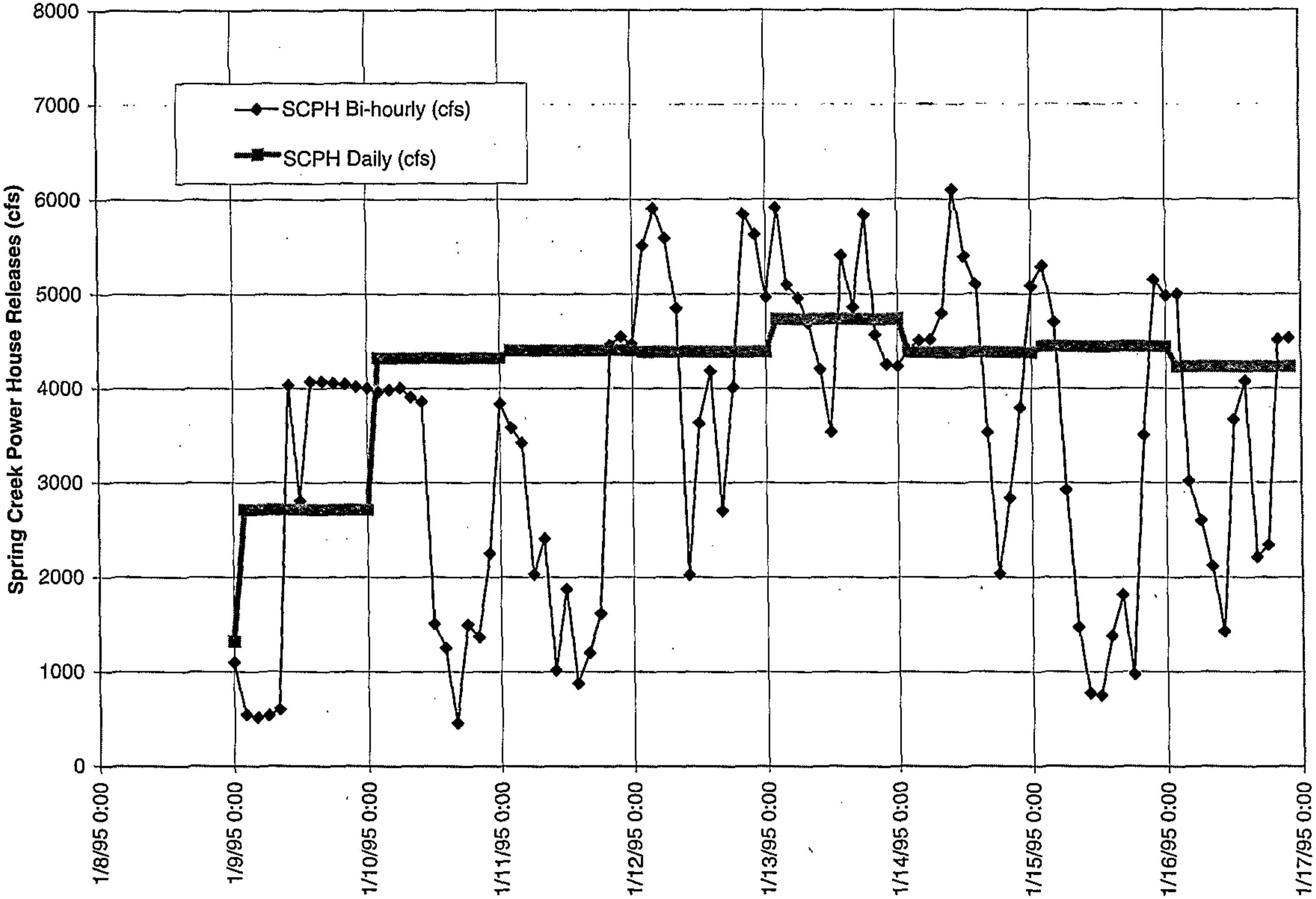

FIGURE B-6
SPRING CREEK POWER HOUSE RELEASES
IRON MOUNTAIN MINE, REDDING, CALIFORNIA

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Early January 1995 Storm

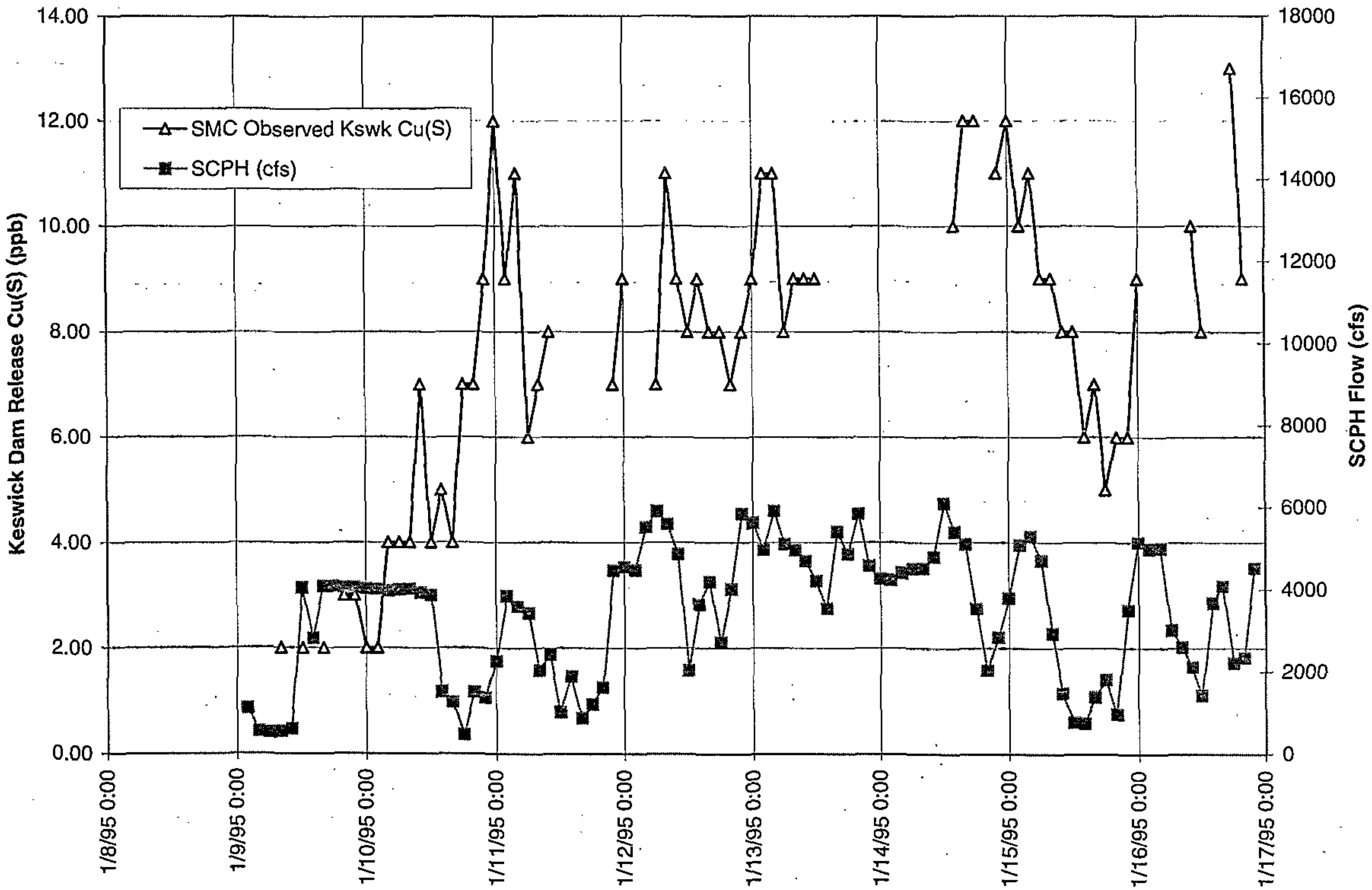

FIGURE B-7
KESWICK DAM DISSOLVED COPPER WITH SCPH FLOWS
IRON MOUNTAIN MINE, REDDING, CALIFORNIA

Figure B-8 depicts the variability in the calculated copper precipitation rate with the variability in the SCPH releases during the early January 1995 storm.

Figure B-9 depicts the SCPH releases during the March 1995 storm.

- The Shasta Dam releases during this period are typical of SCPH release operations during a late season storm in which flood control parameters control the operations of Whiskeytown Lake.
- During this period, the powerhouse would be expected to produce maximum power under base load conditions. Flows in excess of the powerhouse capacity were released over the dam into Clear Creek. Little flow variability would be expected over the course of a day of operation.
- The lack of variability in the SCPH releases during these periods would be expected to reduce the level of uncertainty associated with SCDD operations to dilute the IMM metal discharges.

Figure B-10 depicts the variability in the dissolved copper concentrations observed in the Sacramento River below Keswick Dam with the variability in the SCPH releases during the March 1995 storm.

Figure B-11 depicts the variability in the calculated copper precipitation rates with the variability in the SCPH releases during the March 1995 storm.

Issues and Concerns

Accurate SCPH release rate flow information is required to successfully manage a potential remedial action that would depend on these flows to safely dilute IMM AMD metal discharge loads.

Bi-hourly CVP operations data indicate significant variability in the SCPH release because it is generally relied on to produce peak power.

Daily average SCPH release flowrates could be considered as adequate input to the Keswick Reservoir mass balance. However, significant uncertainty is introduced related to the interaction of the SCPH waters and the IMM metal discharges from the SCDD.

Reliance on "daily average" values introduces significant uncertainty into the Keswick Reservoir mass balance during periods in which peak power production defines the Shasta Dam and SCPH releases. These peak discharges are stored in Keswick Reservoir and released into the Sacramento River to regulate river flow. The storage and later release of these waters impacts the physical availability of waters in the lower third of Keswick Reservoir to assure dilution of the IMM contaminant inflows.

The release rates reported by the USBR in its operations summary are values as of 12:00 midnight on the reporting day. Operational parameters are often modified over the course of a day. The assumption that the reported values are reliable estimates for "daily average" release rates introduces some uncertainty into the mass balance calculation.

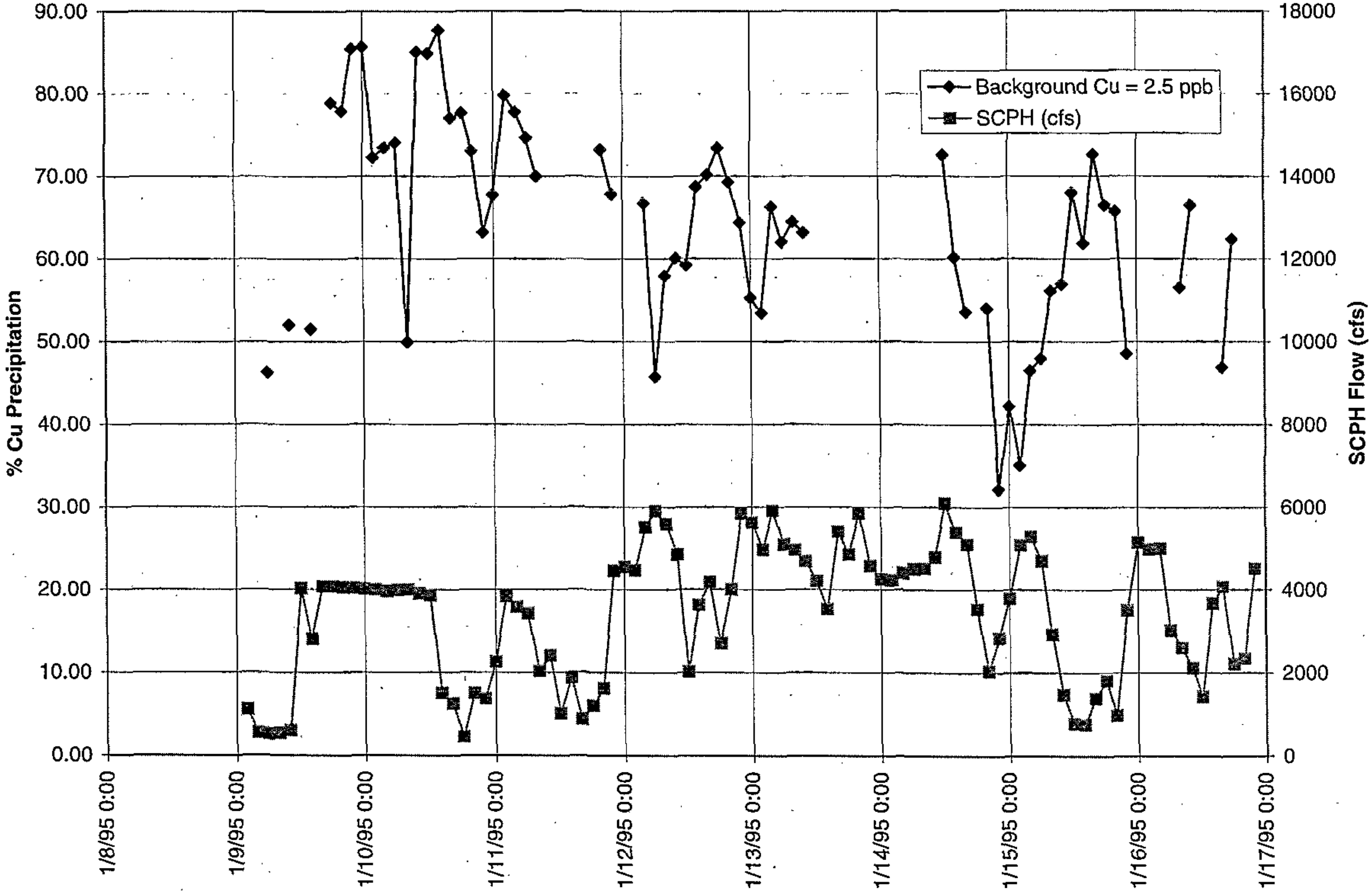

FIGURE B-8
COPPER PRECIPITATION WITH SCPH FLOWS
IRON MOUNTAIN MINE, REDDING, CALIFORNIA

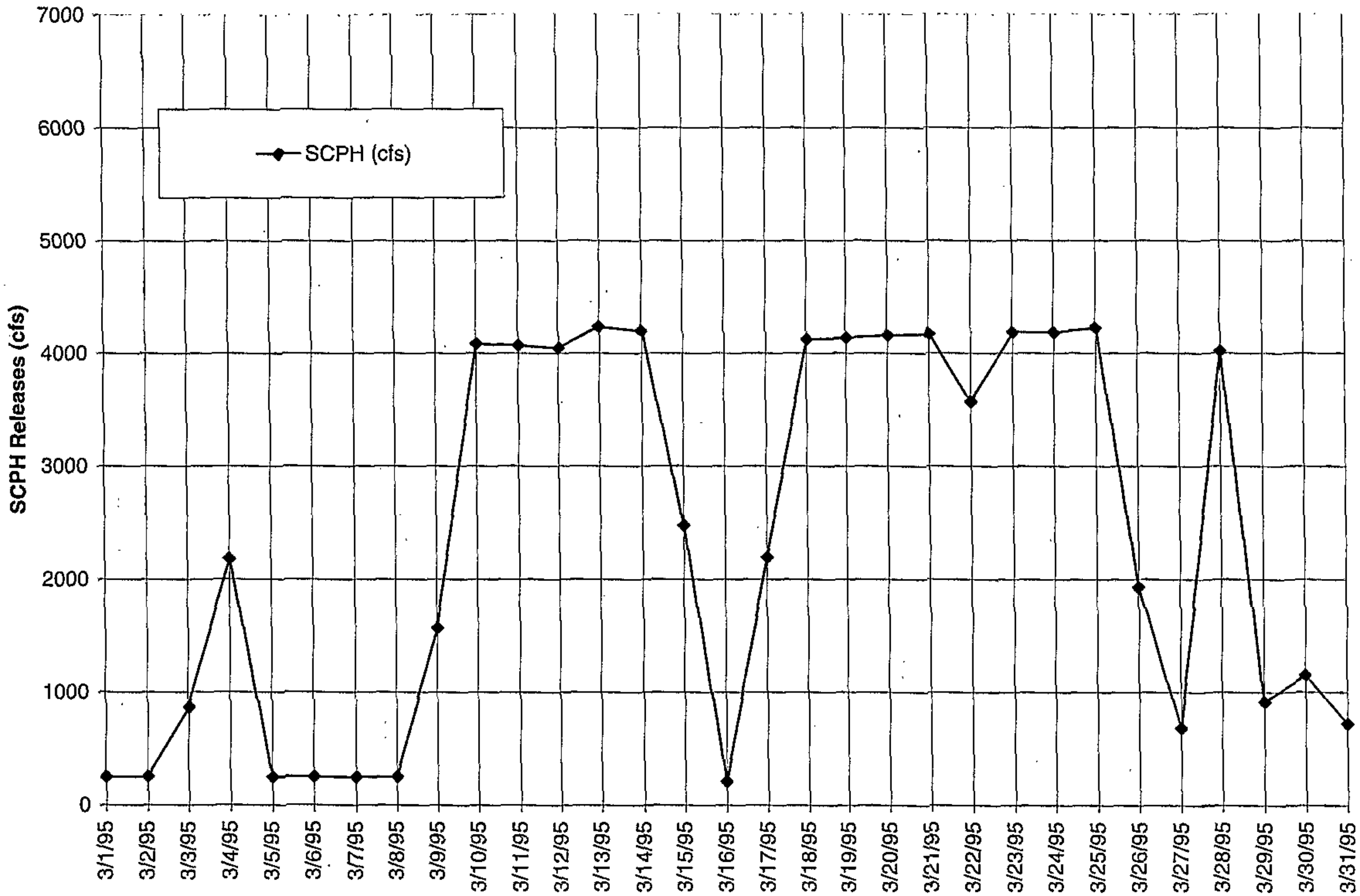

FIGURE B-9
SPRING CREEK POWER HOUSE RELEASES
IRON MOUNTAIN MINE, REDDING, CALIFORNIA

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March 1995 Storm

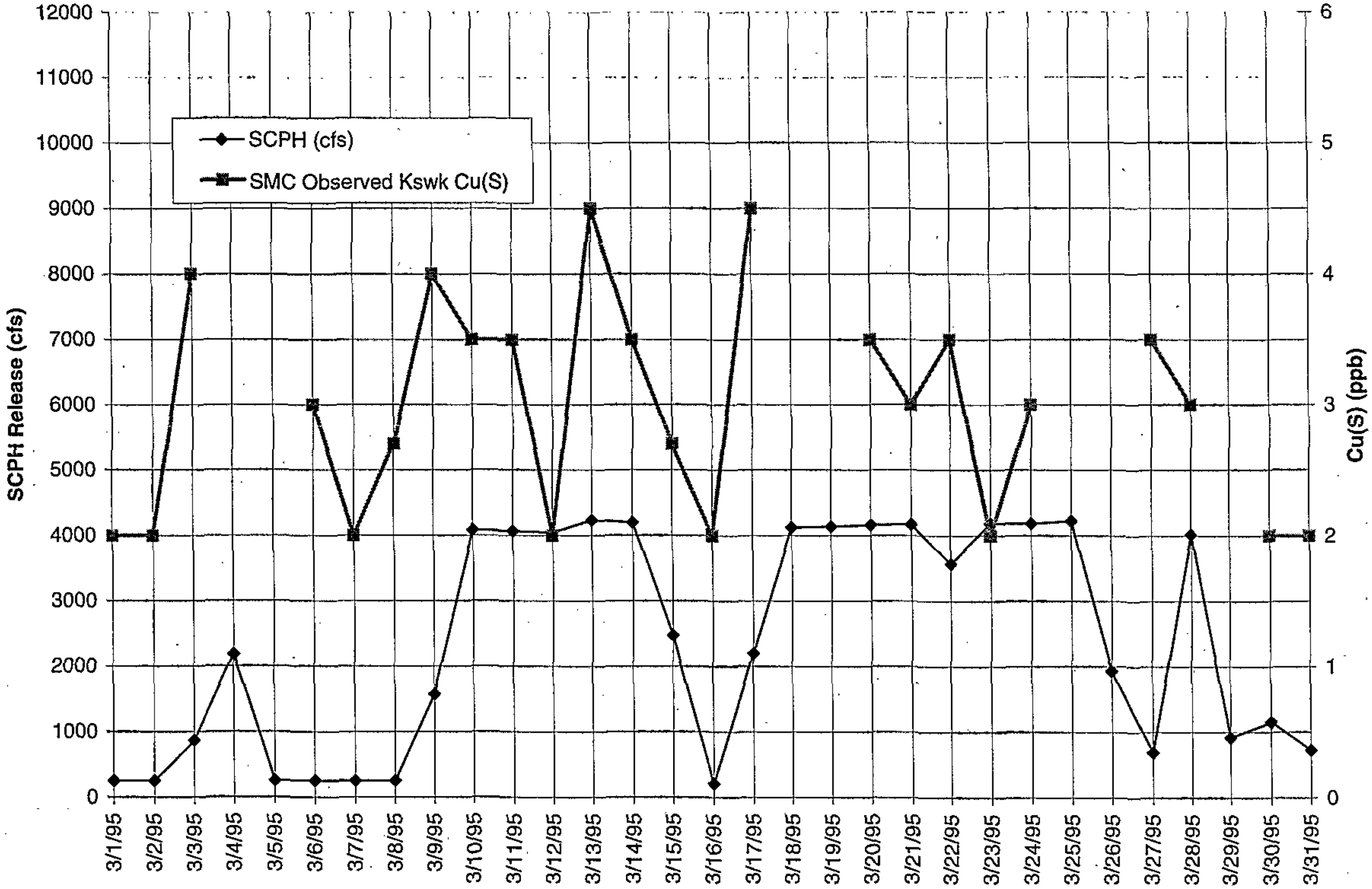

FIGURE B-10
KESWICK DAM RELEASE
COPPER CONCENTRATION
IRON MOUNTAIN MINE, REDDING, CALIFORNIA

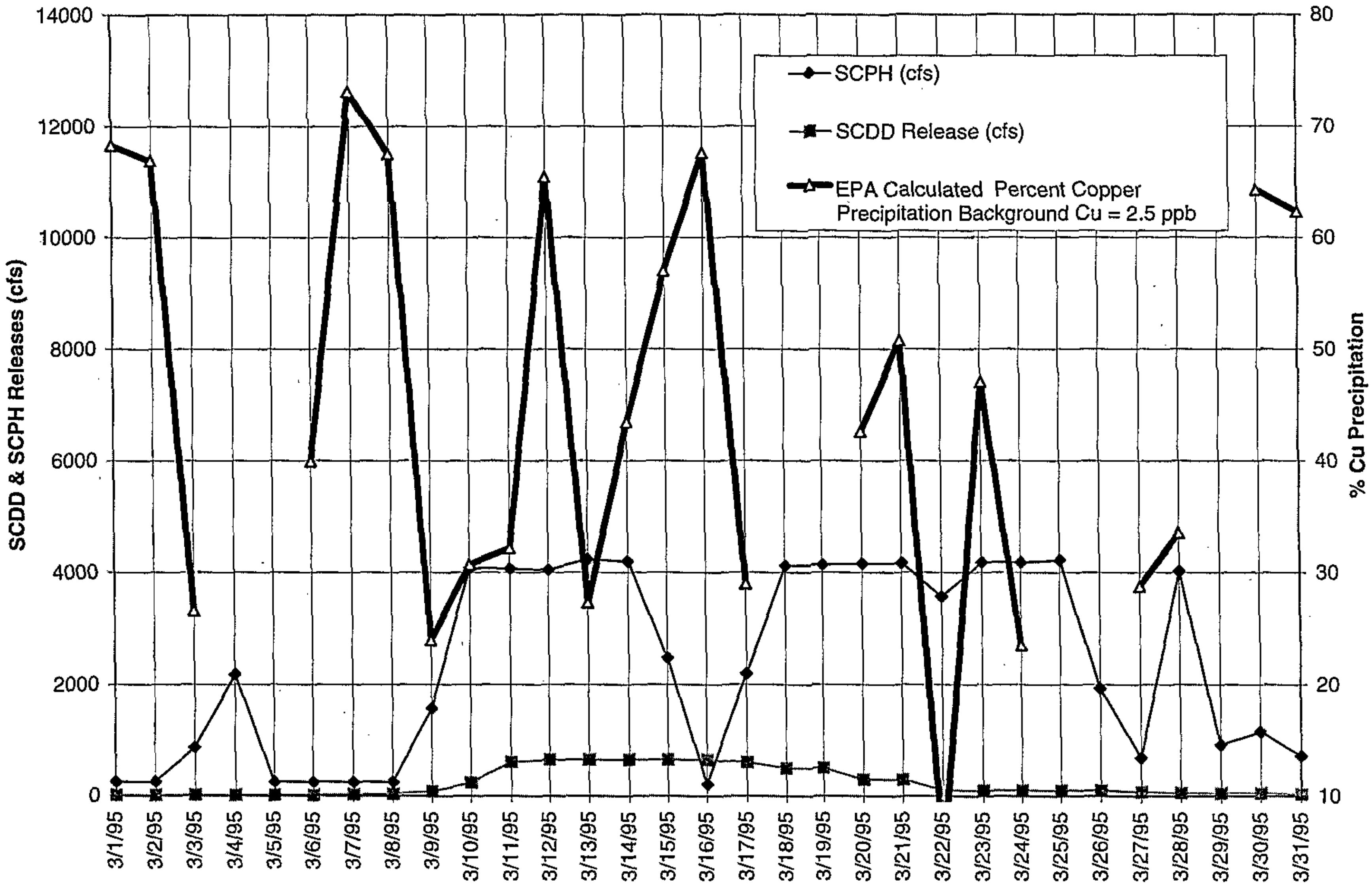

FIGURE B-11
SCDD AND SCPH RELEASES
v. COPPER PRECIPITATION
IRON MOUNTAIN MINE, REDDING, CALIFORNIA

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March 1995 Storm

Variability in the SCPH discharges impacts the physical and chemical processes that occur in SCAKR as the IMM metal discharges are diluted and then transported into Keswick Reservoir and the Sacramento River.

The SCPH release rates are directly related to power production. The release rates derived from power production records are considered to be accurate flow measurements.

The USBR operational summary is currently maintained for USBR record keeping and operational decision making requirements. It is not intended for use as engineering information of the sort needed for the performance of the Keswick Reservoir mass balance. Future reliance on such an operational record for engineering data to be input into the Keswick Reservoir mass balance requires that the accuracy and precision of the operational record be assured through stringent quality control and quality assurance procedures for the record keeping focused on assuring the validity of the operational record for use as appropriate engineering data.

Whiskeytown Lake/Spring Creek Powerhouse Release Water Quality

Water quality of releases from SCPH can be an important factor with respect to managing SCDD releases of IMM metals under certain controlled release conditions. Although the SCPH releases are not generally the dominant component of the Keswick Reservoir water balance, at times essentially all of the Keswick Dam release originates from the SCPH releases. The IMM historic data set indicates that the SCPH release water quality is not highly variable.

The preferred approach would be to acquire "real time" water quality data to characterize the SCPH releases. However, analytical techniques are not available to allow for "real time" analysis of copper, zinc, and hardness.

The second best approach would be to analyze a representative water quality sample as soon as practicable. However, the time delay associated with the performance of field sampling and the water quality analysis turn-around time is a significant factor in assuring "real time" water management operations to safely dilute the IMM metal discharges. Performing frequent sampling and expediting analysis of the sample would enhance operation efficiency. Frequent sampling and expediting analysis of the sample would significantly increase the associated cost.

The third best approach is to rely on a historic data set to characterize the SCPH releases for operational purposes. The historic IMM data set indicates that the discharges from the SCPH are not highly variable and average 1.3 ppb of dissolved copper. This average appears to be a reasonable estimate of the water quality of the SCPH releases. Further study is required to confirm this observation. Under this approach, a conservative estimate of the average metal content must be relied on for purposes of the mass balance if the SBPS are to be attained.

Data Availability

The IMM data base contains dissolved copper and zinc data for the SCPH discharges over the period of EPA's Superfund cleanup action. Data acquired during EPA's studies of the IMM site indicate that the SCPH copper releases average 1.3 ppb. (See 1996 WMFSA, Volume II, Appendix C.4.2)

The USBR currently acquires water quality data regarding the SCPH release only occasionally. However, the USBR does not report "dissolved" metal values. The USBR protocol specifies reporting "total soluble" metal concentrations (field acidification of the sample prior to filtering and analysis). This protocol is a conservative approach for managing reservoir operations that would provide a factor of safety to assure that "dissolved" metal concentrations would not exceed the protective SBPS.

The USBR has the capability to analyze the water quality samples locally. However, the reported detection limit for copper is currently 2 ppb, and is not adequate to accurately characterize the SCPH Dam releases. Analytical capability of measuring 0.5 ppb copper is required. The USBR may be able to upgrade its analytical capability or contract with a local laboratory for the required analytical support.

Issues and Concerns

There is significant uncertainty with respect to the practicability of analytical characterization of the quality of the SCPH releases during "real time" CVP operations because of:

1. The time required to perform field sampling and acquire a representative sample

2. The time required to perform the water quality analysis of the sample, quality assure the analysis and data, and report the water quality analysis results to operational personnel

3. The limitations of analytical procedures associated with measuring metal concentrations at these low to very low concentration levels

However, the potential for variability in water quality of the SCPH releases appears to be low.

An alternate approach is to rely on the historic data set to define average SCPH release metal concentrations. Uncertainty, necessitating some operational allowance, is introduced in this alternate approach by:

1. The potential for some limited variability in water quality of the SCPH releases, particularly during storm periods

2. The limitations of the historic data set to adequately define the SCPH release water quality under varying antecedent moisture and storm conditions

3. The analytical limitations associated with measuring metal concentrations at these low to very low concentration levels

Analytical capability to accurately measure metal concentrations at the levels present in SCPH releases requires a very high level of quality assurance.

Documents in the IMM Administrative Record indicate that limitations inherent in current analytical techniques may produce results that are uncertain by as much as 0.2 to 0.3 ppb copper. Relative to the SCPH releases, this may be as much as 10 to 30 percent of the actual sample value, but in comparison to the protective SBPS, this error would be approximately 3.6 to 5.4 percent. This analytical limitation introduces an additional small uncertainty into the mass balance analysis for these waters.

EPA has performed a sensitivity analysis to assess the many uncertainties involved in a Keswick Reservoir mass balance calculation. These analyses support the conclusion that data uncertainties are an important consideration in the interpretation of the mass balance results.

Reliance on historical data for the SCPH introduces some uncertainty into the calculation, but probably less uncertainty than is introduced by this approach with respect to other inputs, such as Shasta Lake, accretion flows, SCDD, and Keswick Dam.

Keswick Reservoir Accretion Flows

Keswick Reservoir accretion flows, or storm water inflows to Keswick Reservoir, are characterized by the peak nature of the inflows.

During early season storms these Keswick Reservoir inflows can at times provide a significant component of the Keswick Reservoir water balance for the period of the peak inflows.

Accretion flows can be estimated from CVP operations reports regarding Spring Creek Reservoir (SCR) inflows and an area-apportionment approach. CVP operational records for the SCR inflows must be reviewed to identify reporting inaccuracies, and limitations of the record with respect to characterizing the peak nature of the SCR inflows must be supplemented to assure an accurate mass balance calculation.

During periods when the accretion flows provide the primary component of the Keswick Reservoir water balance, these accretion flows also provide a significant metal input to the mass balance for Keswick Reservoir.

The accretion flows have varying copper concentrations that range from values that are very low to values that are at or near the protective SBPS concentrations. EPA data acquired during the 1995-1996 wet season indicate that the area-weighted average of the accretion flows is 4.3 ppb for dissolved copper and 19 ppb for dissolved zinc.

The available data set that can be relied on to characterize the water quality of the Keswick Reservoir accretion flows is limited. To date it has been necessary in performing modeling with the IMM WQM to assume an average concentration for these flows based on the available data.

There is some uncertainty with respect to characterization of the quality of these waters because of limitations of the accuracy of water quality analysis procedures at these low copper levels.

Data from the storm of 1995 support the conclusion that accretion flows generally are waters with low hardness that can significantly reduce the overall hardness of the Sacramento River during storms. Since the protective SBPS vary with hardness, the standard would be lower at times with high accretion flows. Further study is required regarding this issue.

Accretion flows may at times be a significant source of suspended particulate matter. SMC has hypothesized that the high levels of particulates may contribute to increase metal precipitation rates through an adsorption process. Further study is warranted.

Keswick Reservoir Accretion Flowrates

Keswick Reservoir accretion flows can best be estimated by calculation based upon measured inflows to the SCR and an area-apportionment technique.

Data Availability

Bi-hourly USBR operations data for SCR inflows are not widely reported, but are available in an electronic database. The USBR has relied on this detailed record to make operational decisions regarding Keswick Reservoir CVP facilities during past major storm events. .

USBR CVP daily operations summary reports are much more widely available than the Bureau's bi-hourly data. The release rates reported by the USBR in its operations summary are values as of 12:00 midnight on the reporting day. These release rates provide information that can be relied upon to estimate the "daily average" flowrate of this high volume Shasta Lake release.

Characteristics

Figure B-12 depicts the calculated Keswick Reservoir accretion flows during the early January 1995 storm.

- The peak nature of the Keswick Reservoir accretion flows during this period is typical of storm period inflows to the reservoir.
- The peak accretion flows were regulated by Keswick Dam to maintain a stable flow regime in the Sacramento River.
- The accretion flows were stored in Keswick Reservoir and only later released. This storage function of Keswick Reservoir complicates the analysis of the chemical and physical processes that would assure dilution of the IMM metal discharges to safe levels.
- The peak nature of the Keswick Reservoir accretion flows would be expected to introduce variability in the metal concentrations observed below Keswick Dam.
- An accurate Keswick Reservoir storage and transport component to the IMM WQM would be a difficult and complex model to develop and calibrate.

Figure B-13 compares the calculated Keswick Reservoir accretion flows during the early January 1995 storm to the Keswick Reservoir inflows. The accretion flows were a major component of the reservoir inflows only early in the storm period.

Figure B-14 depicts the calculated Keswick Reservoir accretion flows with the calculated copper precipitation rate during the early January 1995 storm. There is no clear correlation between the peak accretion flows and the observed copper precipitation rates.

Figure B-15 depicts the calculated Keswick Reservoir accretion flows during the March 1995 storm.

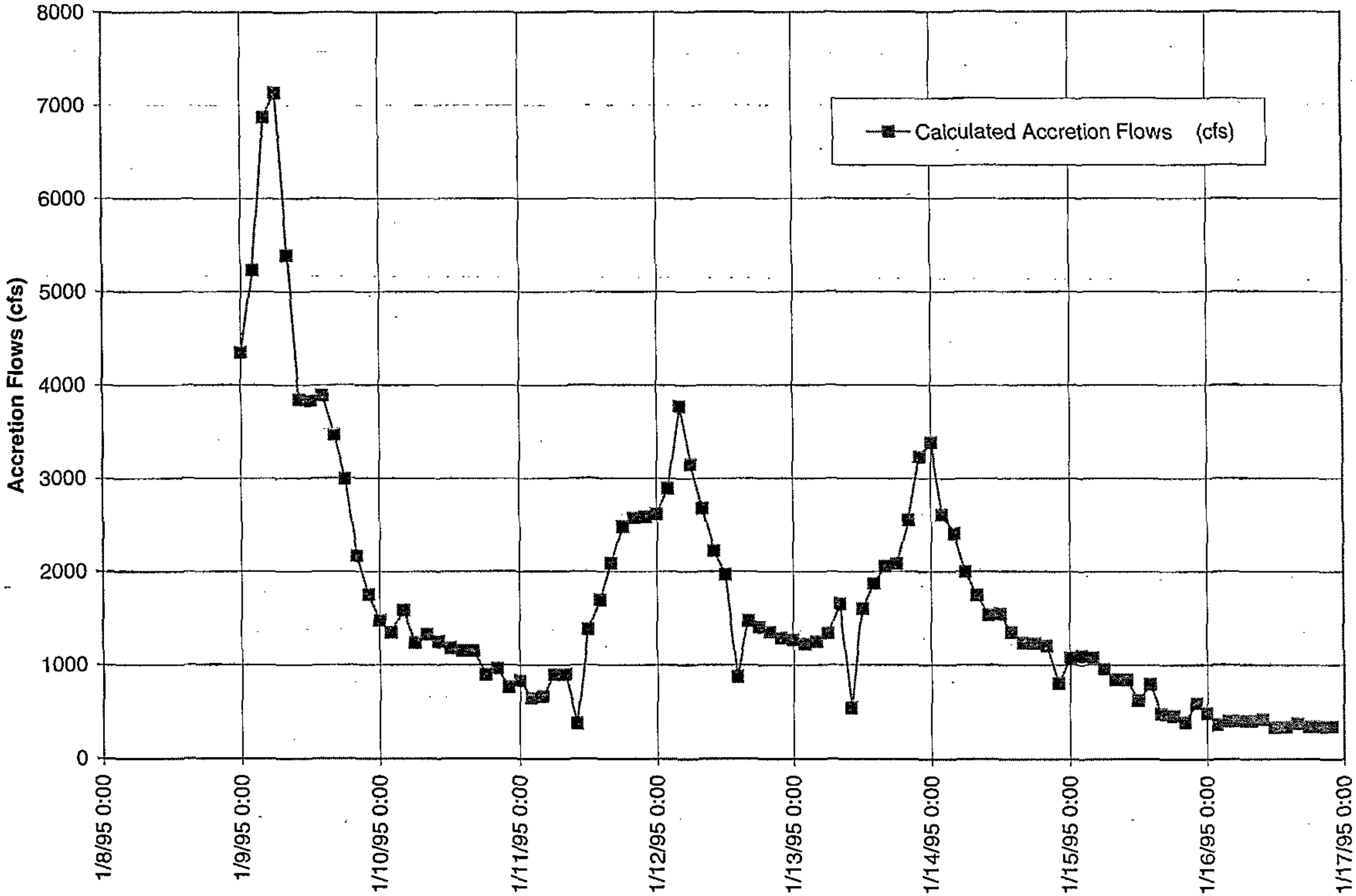

FIGURE B-12
CALCULATED KESWICK RESERVOIR ACCRETION FLOWS
IRON MOUNTAIN MINE, REDDING, CALIFORNIA

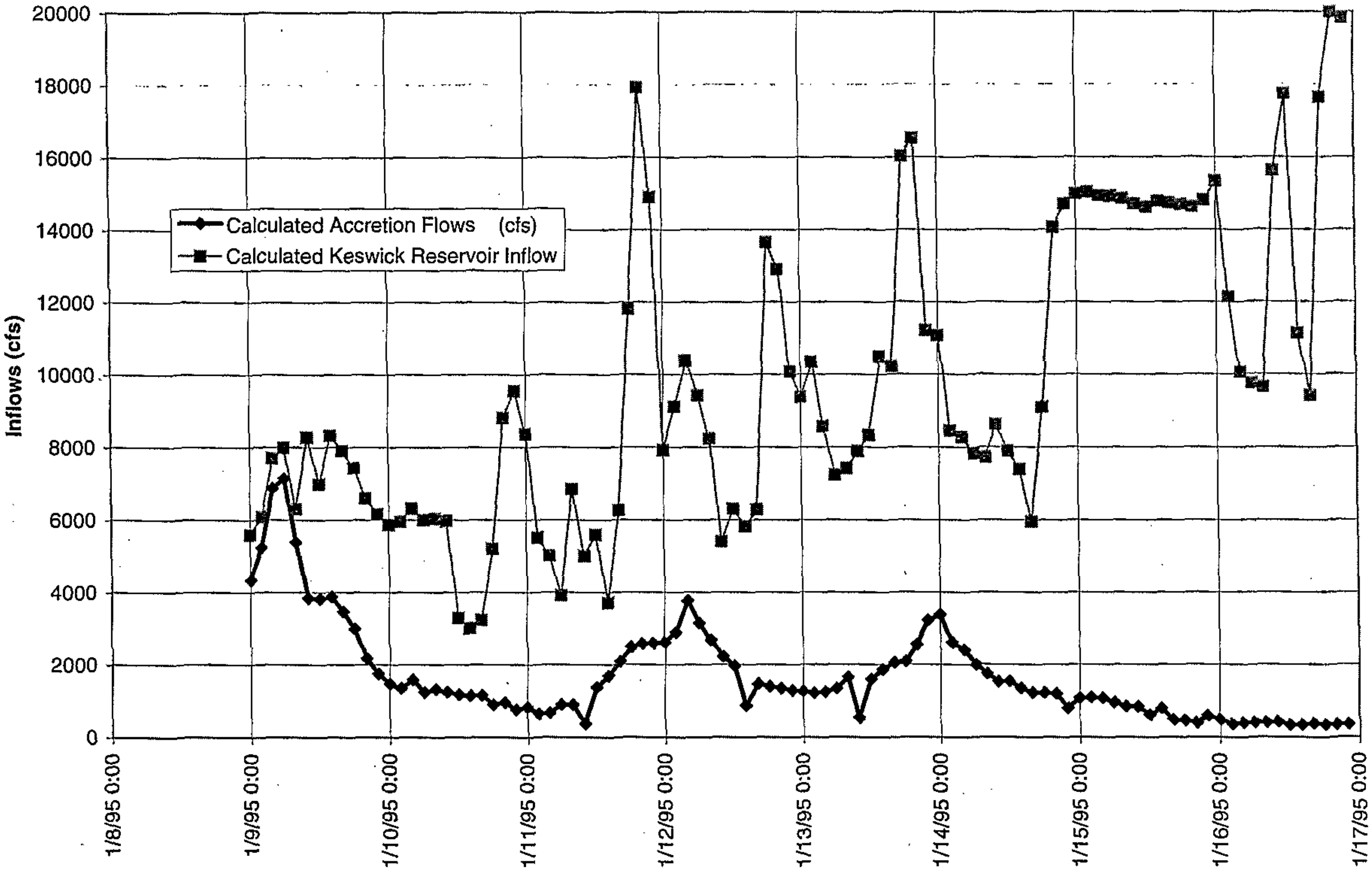

FIGURE B-13
KESWICK RESERVOIR INFLOWS AND ACCRETION FLOWS
IRON MOUNTAIN MINE, REDDING, CALIFORNIA

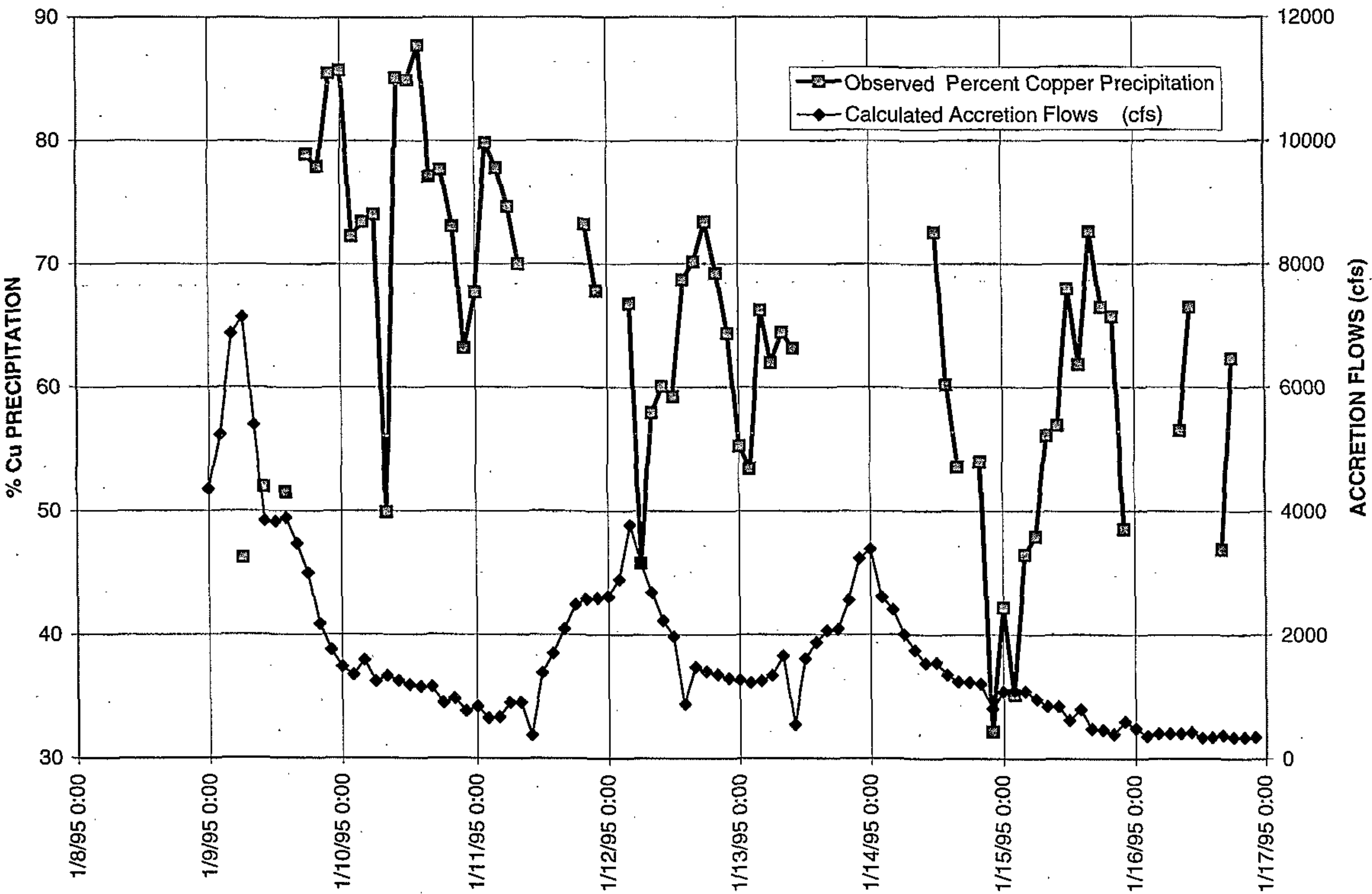

FIGURE B-14
KESWICK RESREVOIR COPPER PRECIPITATION AND ACCRETION FLOWS
IRON MOUNTAIN MINE, REDDING, CALIFORNIA

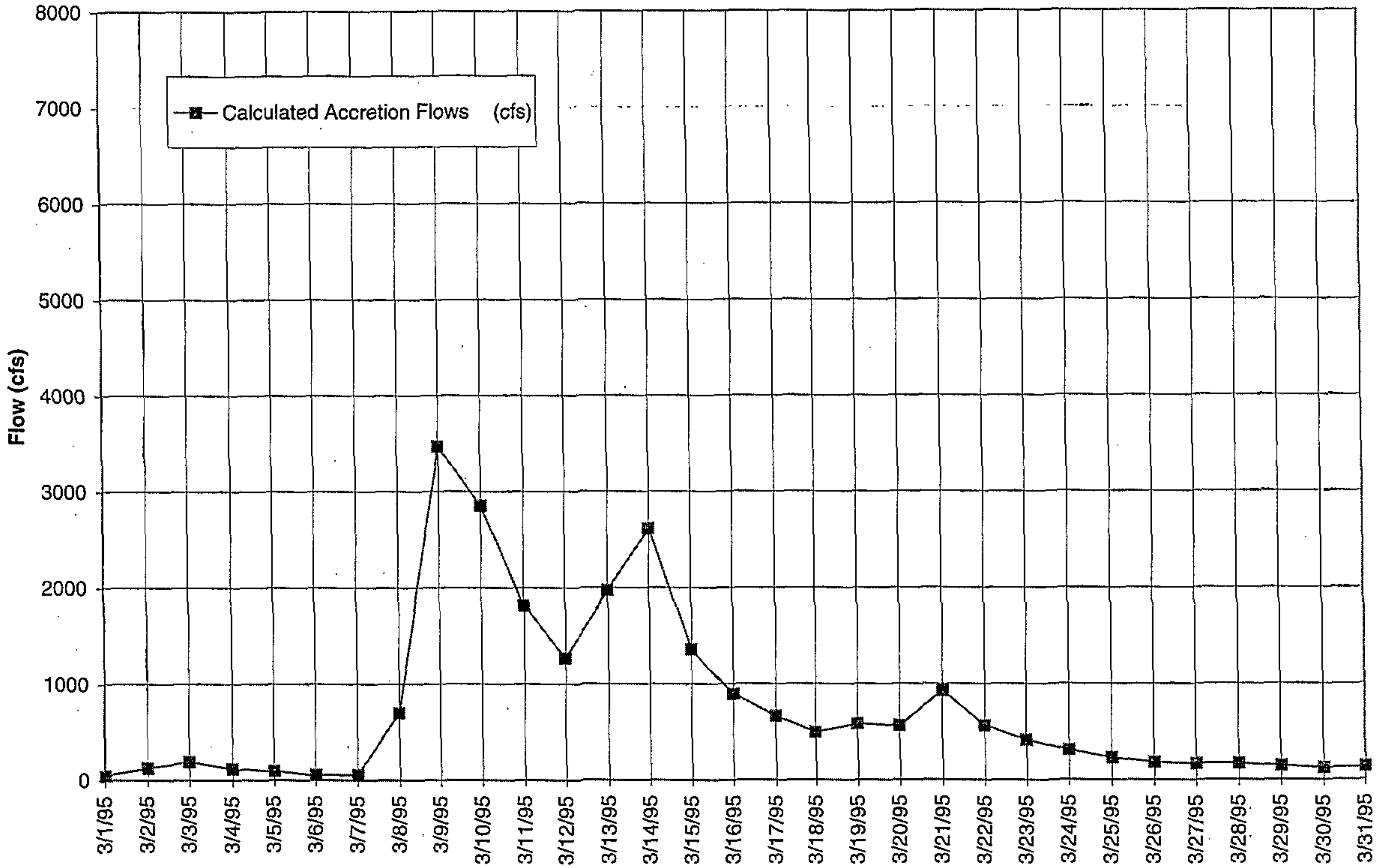

FIGURE B-15
KESWICK RESERVOIR
ACCRETION FLOWS
IRON MOUNTAIN MINE, REDDING, CALIFORNIA

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March 1995 Storm

Figure B-16 compares the calculated Keswick Reservoir accretion flows with the Shasta Dam releases during the March 1995 storm.

Issues and Concerns

During periods when the accretion flows are a significant component of the Keswick Reservoir inflow, accurate Keswick Reservoir accretion flowrate information is required to successfully manage a potential remedial action that would depend on these flows to safely dilute IMM AMD metal discharge loads.

Bi-hourly CVP operations data can be relied on to calculate accretion flows by relying on the SCR inflows. However, uncertainty is introduced by the limitations on the accuracy of this approach. Gaged flow information to measure the numerous distinct accretion flows would be difficult to acquire.

The SCR inflow rates reported by the USBR in its operations summary are values as of 12:00 midnight on the reporting day. The assumption that the reported values are reliable estimates for "daily average" release rates during storm periods introduces some uncertainty into the mass balance calculation.

Daily average Keswick Reservoir accretion flowrates could be calculated and considered as adequate input to the Keswick Reservoir mass balance. However, significant uncertainty is introduced because of the extreme peak nature of the accretion flows.

Reliance on "daily average" values introduces significant uncertainty into the Keswick Reservoir mass balance during periods of peak accretion flows. These peak discharges are stored in Keswick Reservoir and released into the Sacramento River to regulate river flow. The storage and later release of these waters impacts the physical availability of waters in the lower third of Keswick Reservoir to assure dilution of the IMM contaminant inflows.

The USBR operational summary is currently maintained for USBR record keeping and operational decision making requirements. It is not intended for use as engineering information of the sort needed for the performance of the Keswick Reservoir mass balance. Future reliance on such an operational record for engineering data to be input into the Keswick Reservoir mass balance requires that the accuracy and precision of the operational record be assured through quality control and quality assurance procedures for the record keeping

Keswick Reservoir Accretion Flow Water Quality

Keswick Reservoir accretion flow water quality is an important factor with respect to managing SCDD releases of IMM metals under controlled release conditions at times when the accretion flows would be a significant component of the Keswick Reservoir water balance.

The preferred approach would be to acquire "real time" water quality data to characterize the Keswick Reservoir accretion flows. However, analytical techniques are not available to allow for "real time" analysis of copper, zinc, and hardness.

The second best approach would be to analyze a representative water quality sample as soon as practicable. However, the time delay associated with the performance of field sampling and the water quality analysis turn-around time is a <u>very</u> significant factor in

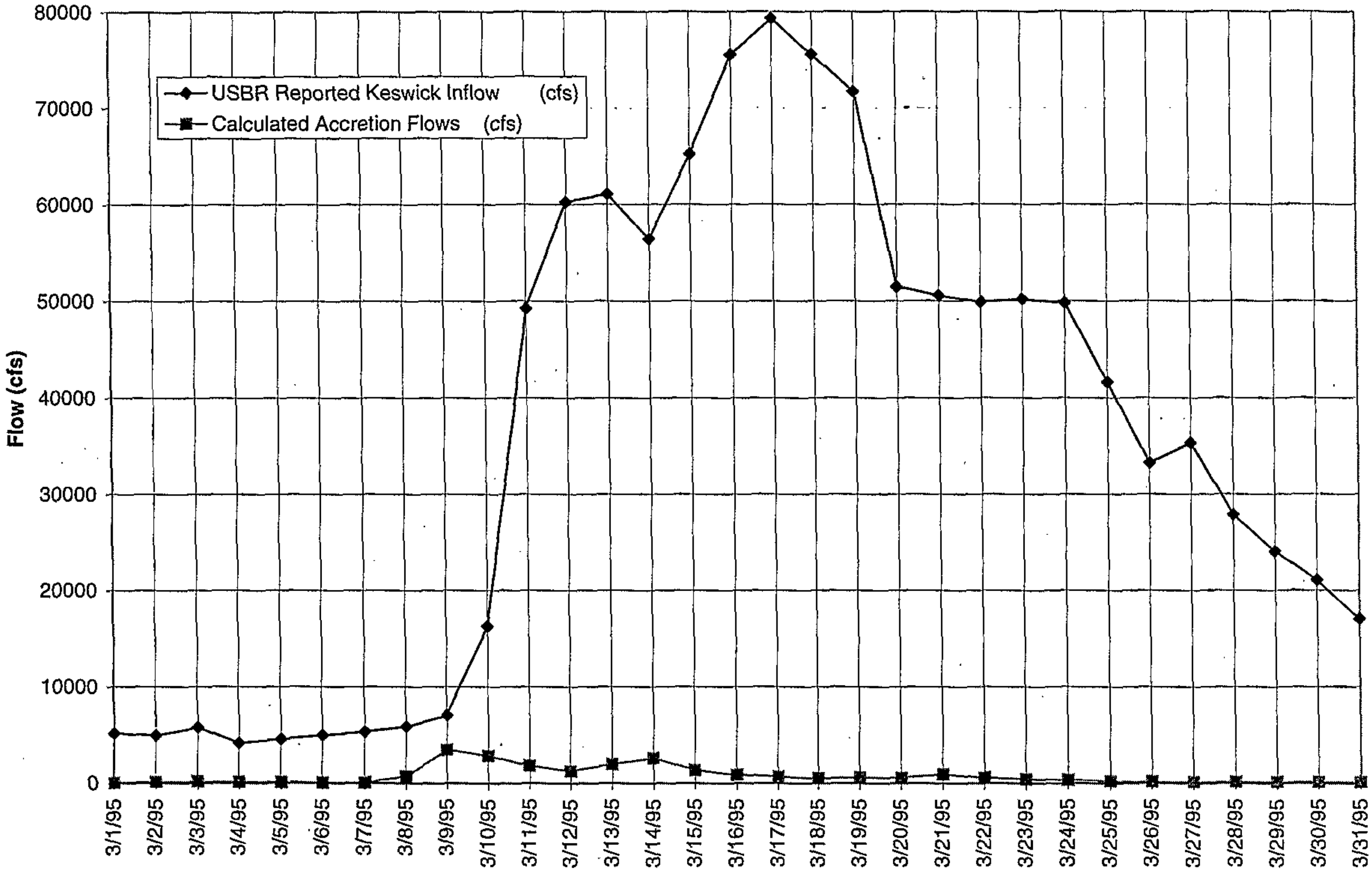

FIGURE B-16
KESWICK RESERVOIR INFLOWS AND ACCRETION FLOWS
IRON MOUNTAIN MINE, REDDING, CALIFORNIA

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March 1995 Storm

assuring "real time" water management operations with respect to the Keswick Reservoir accretion flows. Because the Keswick Reservoir accretion flows derive from a widespread area, it is not practicable to perform frequent sampling combined with expedited analysis of the sample to enhance operation efficiency.

Currently the only viable approaches for characterizing the accretion flows are (1) to update and rely on a historic data set to characterize the Keswick Reservoir accretion flows for operational purposes, or (2) to acquire data from the three major flows on an infrequent but regular basis and rely on those data to predict flows and concentrations for all accretion flows. Under both of these approaches, a conservative estimate of the average metal content, at any given time, must be relied on for purposes of the mass balance if the SBPS are to be attained.

Data Availability

The IMM data base contains a limited amount of dissolved copper and zinc data for the Keswick Reservoir accretion flows over the period of EPA's Superfund cleanup action. The available data indicate that Keswick Reservoir accretion flows have an area-weighted average 4.3 ppb dissolved copper concentration. (See 1996 WMFSA, Volume II, Appendix C.4.1)

EPA currently acquires water quality data regarding the Keswick Reservoir accretion flows on a frequency of once per week during the wet season.

Issues and Concerns

There is currently only very limited information on all background metal inputs, particularly loads associated with the accretion flows. Therefore, these inflows are difficult to characterize, particularly with respect to the variability of the concentrations under differing hydrologic conditions. Refer to EPA's 1996 WMFSA, Volume II, Appendix C.4.1 and Appendix G.

SMC has provided some data regarding metal inputs from Flat Creek which indicate that Flat Creek contains higher concentrations than other background waters. SMC has not provided data regarding metal concentrations in Motion Creek or other identifiable accretion flows.

EPA's 1995-1996 water year sampling efforts have established that the Keswick Reservoir accretion flows contained significant levels of metals (area-weighted average of 4.3 ppb dissolved copper and 19.4 ppb dissolved zinc. These reported metal concentrations would limit the use of the Keswick Reservoir accretion flows for dilution of IMM metal discharges.

Loads associated with accretion flows are expected to be relatively small during time periods when accretion flow volumes are small relative to other Keswick Reservoir inflows.

Keswick Dam Releases

Keswick Dam releases can generally be characterized as high to very high volume releases.

USBR CVP operations information can be relied upon to accurately estimate these high volume Keswick Dam releases. Because Keswick Dam releases are relied upon to regulate the flow of the Sacramento River, these releases are the most stable of the releases from CVP facilities in the Keswick Reservoir system.

In the future, after implementation of EPA's remedy for the IMM heavy metal discharges, controlled release operations are expected to be able to assure attainment of these protective SBPS.

During past SCDD spills of IMM AMD, copper concentrations in the Keswick Dam releases have significantly exceeded the protective SBPS.

There is some uncertainty with respect to characterization of the quality of these waters. In general, it can be difficult to assure the representativeness of water quality samples taken below Keswick Dam (particularly during storm periods with high accretion flows). Some uncertainty is also present due to limitations of the accuracy of water quality analysis procedures at these low copper levels.

Keswick Dam Release Flowrates

Keswick Dam release rates can be determined by (1) correlation with power production records; and (2) calculation based upon changes in the Keswick Reservoir elevation and known operational settings.

Data Availability

Although not widely available, bi-hourly USBR operations data are available in an electronic database. The USBR has relied on this detailed record to make operational decisions regarding CVP facilities near Keswick Reservoir during past major storm events. The bi-hourly operations data indicate that the Keswick Dam releases are not highly variable because the releases are maintained to provide regulation of Sacramento River flow.

USBR CVP daily operations summary reports are much more widely available than the Bureau's bi-hourly data. The release rates reported by the USBR in its operations summary are values as of 12:00 midnight on the reporting day. These release rates provide information that can be relied upon to estimate the "daily average" flowrate of this high volume Keswick Dam release. This approach is generally reliable for purposes of determining the Keswick Dam release because of the role of Keswick Dam releases in river regulation.

Characteristics

Figure B-17 depicts the bi-hourly Keswick Dam releases during the early January 1995 storm.

Figure B-18 compares the "bi-hourly" and "daily average" Keswick Dam releases during the early January 1995 storm.

Figure B-19 compares the "bi-hourly" Keswick Dam releases with the Keswick Reservoir inflows during the early January 1995 storm.

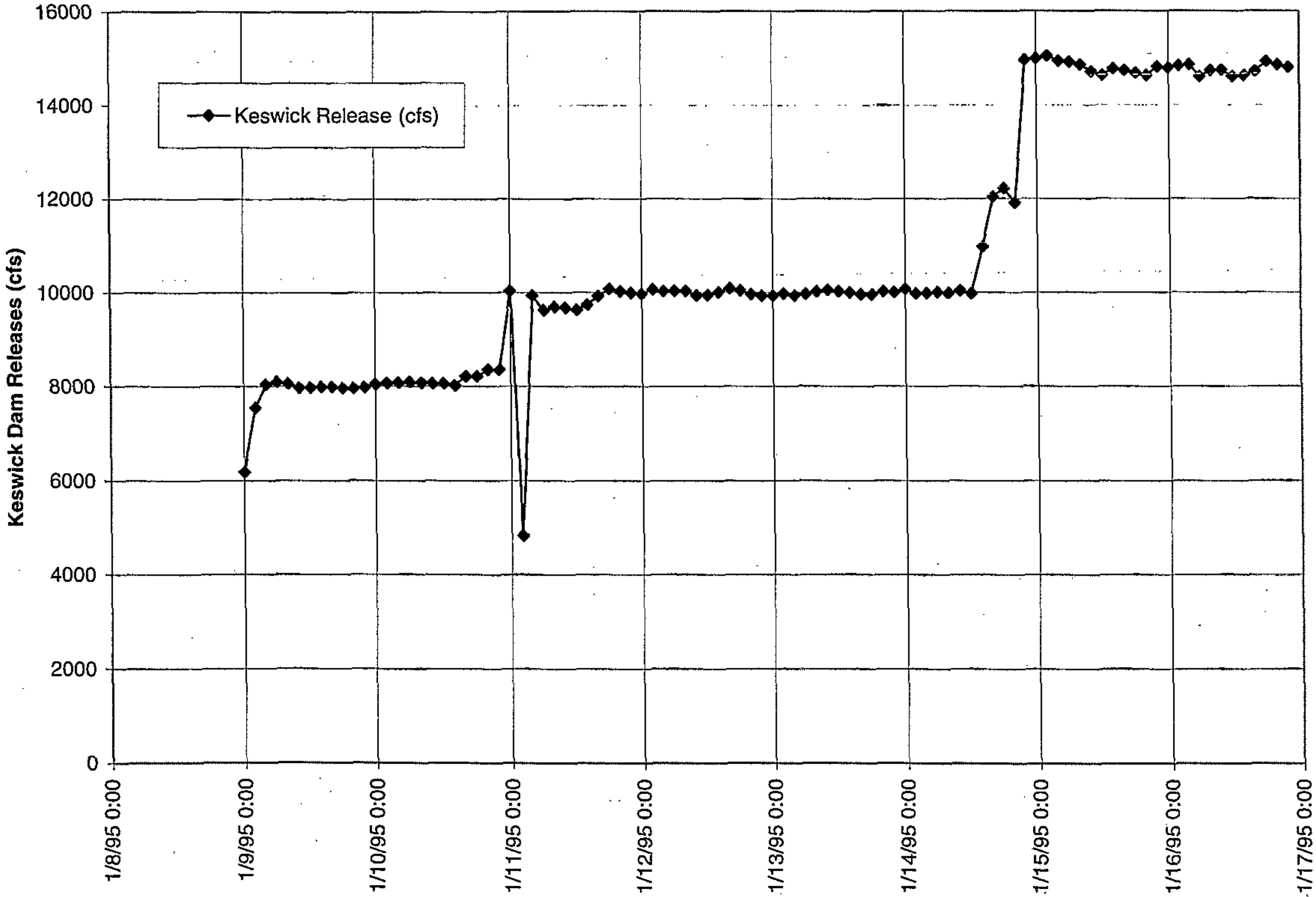

FIGURE B-17
KESWICK DAM RELEASES
IRON MOUNTAIN MINE, REDDING, CALIFORNIA

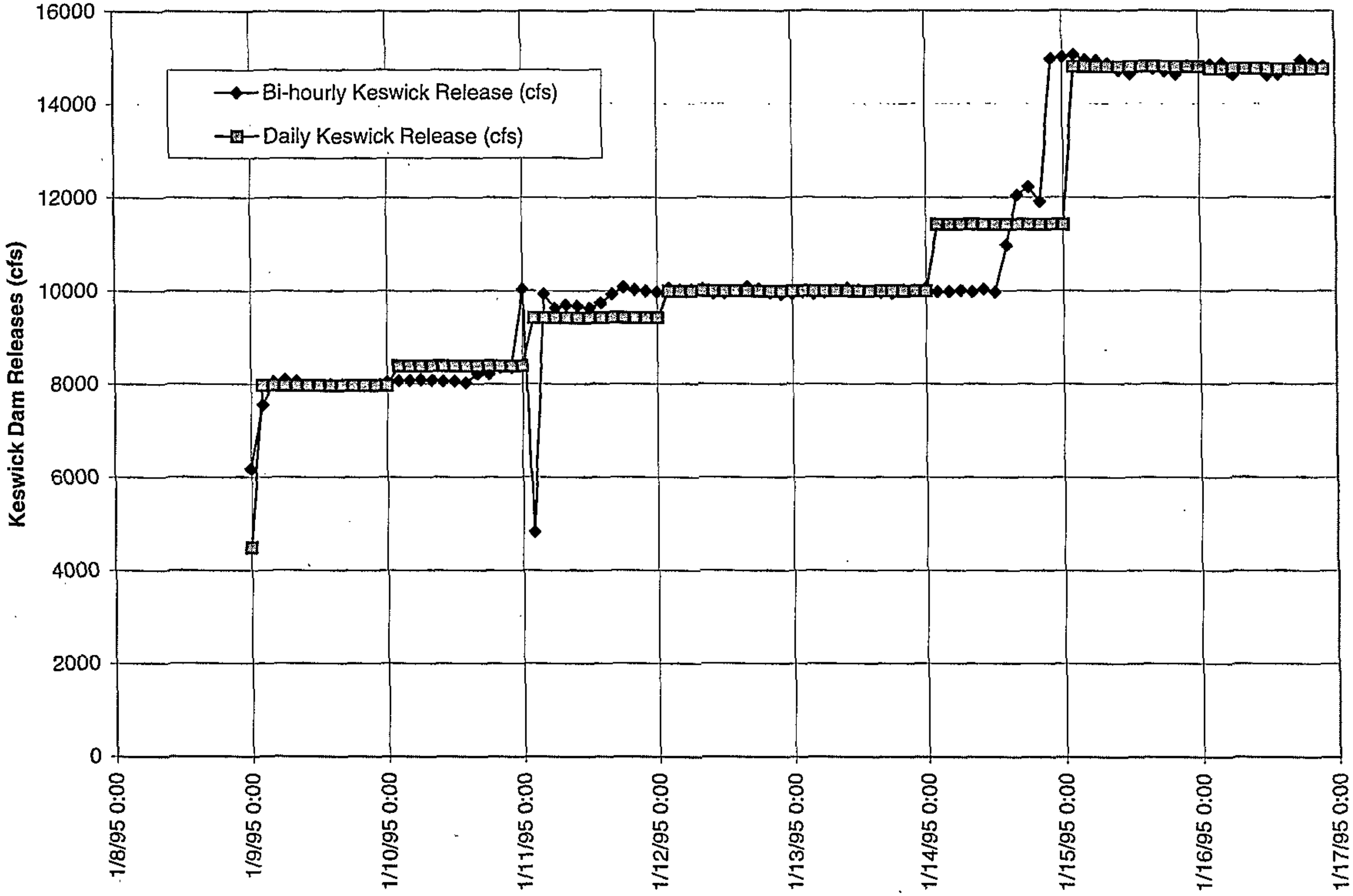

FIGURE B-18
KESWICK DAM RELEASES
IRON MOUNTAIN MINE, REDDING, CALIFORNIA

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Early January 1995 Storm

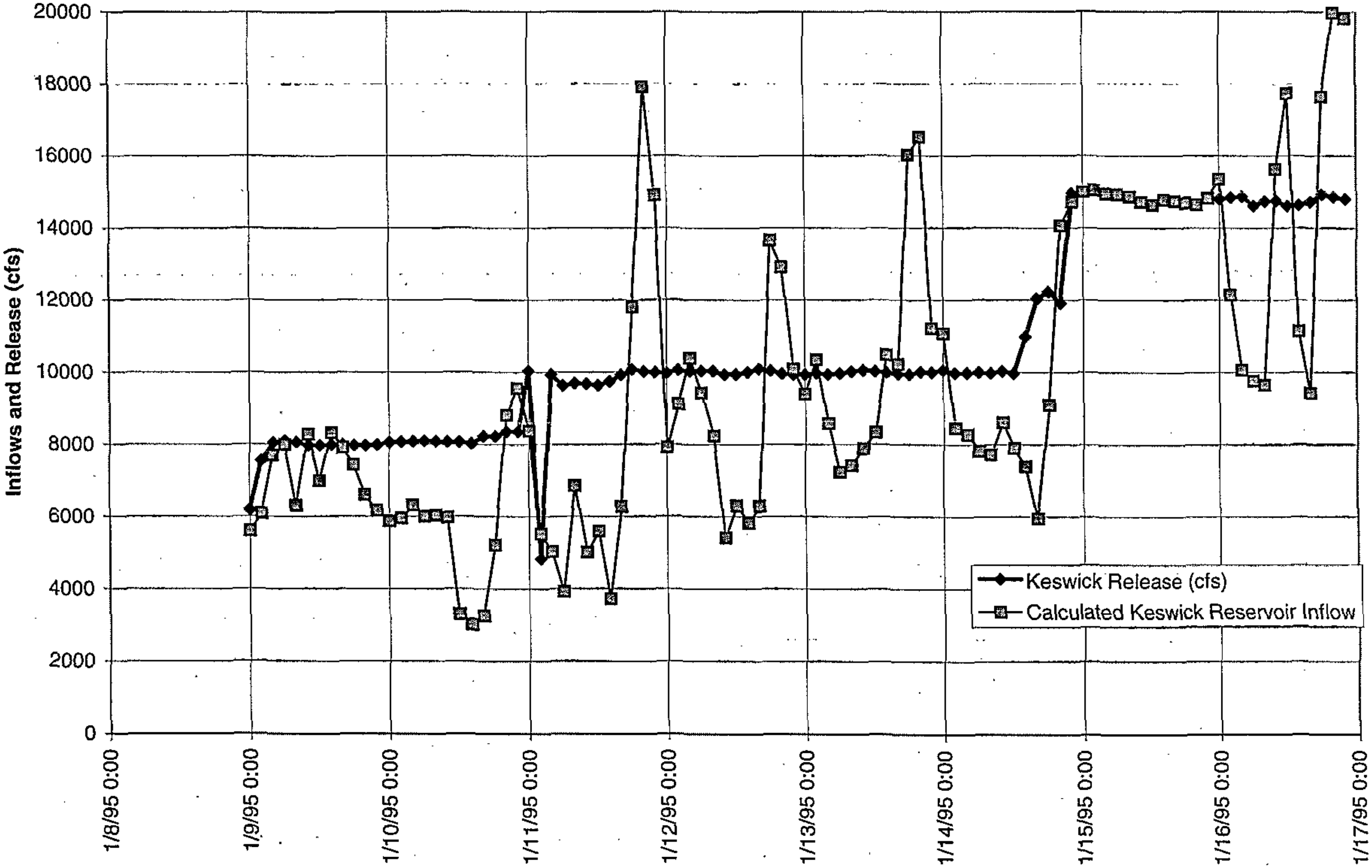

FIGURE B-19
KESWICK RESERVOIR INFLOWS AND RELEASE
IRON MOUNTAIN MINE, REDDING, CALIFORNIA

Figure B-20 depicts the "daily average" Keswick Dam releases during the March 1995 storm.

Issues and Concerns

The measurement and uncertainty associated with the Keswick Dam release rates is an extremely important factor for the performance of the Keswick Reservoir mass balance. The Keswick Dam release rates and metal concentrations define the metal loads discharged to the Sacramento river.

It is extremely important that the flowrates be determined as accurately as possible. Uncertainty associated with the Keswick Dam release flowrates translates directly to uncertainty in the calculated mass balance and allowable SCDD release.

The USBR reported Keswick Dam releases are generally considered to be reliable daily average values. The USBR maintains stable Keswick Dam release rates in order to meet requirements for river regulation. USBR generally evaluates CVP operational parameters and modifies operations for the dam releases on an approximate daily basis.

The Keswick Dam release rates are directly related to power production up to the maximum powerhouse flowrate (approximately 12,000 cfs). The reported release rates are considered to be accurate flow measurements up to that flowrate.

For Keswick Dam release rates greater than the maximum powerhouse flowrates, releases are estimated for USBR operational purposes from powerhouse records, recorded lake elevations, spillway curves, and gate settings. The estimates of these high Keswick Dam release rates is less certain than the lower rates that can be reliably calculated from powerhouse operational records.

The release rates reported by the USBR in its operations summary are values as of 12:00 midnight on the reporting day.

The USBR operational summary is currently maintained for USBR record keeping and operational decision making requirements. It is not intended for use as engineering information of the sort needed for the performance of the Keswick Reservoir mass balance. Future reliance on such an operational record for engineering data to be input into the Keswick Reservoir mass balance requires that the accuracy and precision of the operational record be assured through quality control and quality assurance procedures for the record keeping.

Keswick Dam Release Water Quality

The water quality of Keswick Dam releases is an important factor with respect to protecting the environment of the upper Sacramento River, EPA's primary remedial action objective. As such, Keswick Dam release water quality is also an important factor with respect to managing SCDD releases of IMM metals under controlled release conditions to meet the protective SBPS. The measured quality of the Keswick Dam releases is relied upon to verify that SCDD operations are being implemented effectively.

The preferred approach would be to acquire "real time" water quality data to characterize the Keswick Dam releases. However, analytical techniques are not available to allow for "real time" analysis of copper, zinc, and hardness.

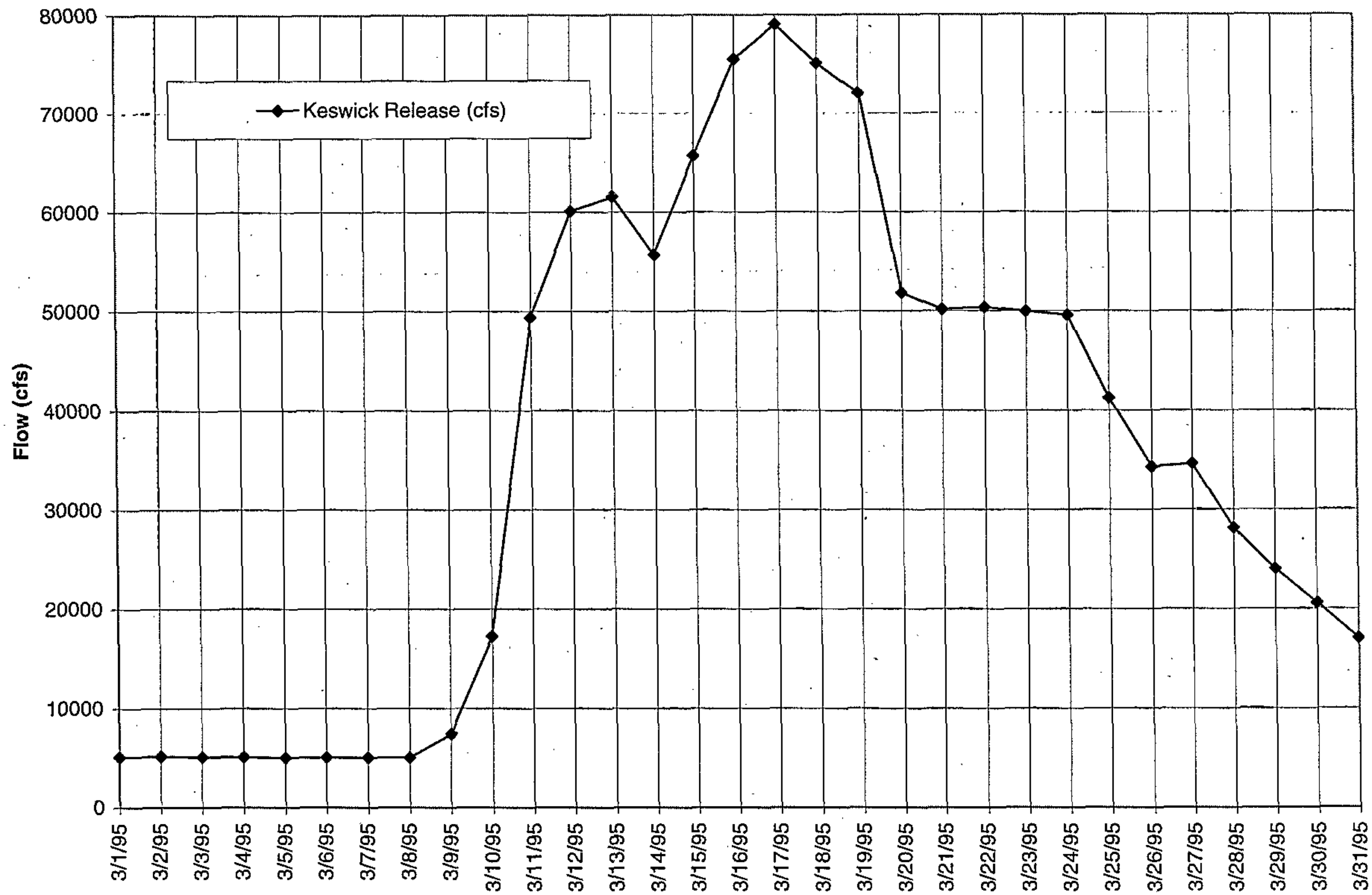

FIGURE B-20
KESWICK DAM RELEASE
IRON MOUNTAIN MINE, REDDING, CALIFORNIA

The second best approach would be to analyze a representative water quality sample as soon as practicable. However, the time delay associated with the performance of field sampling and the water quality analysis turn-around time is a significant factor in assuring "real time" water management operations to safely dilute the IMM metal discharges. Performing frequent sampling and expediting analysis of the sample would enhance operation efficiency. Frequent sampling and expediting analysis of the sample would significantly increase the associated cost.

A third approach, relying on a historic data set to characterize the Keswick Dam release, is not appropriate for SCDD operational purposes. Because of the importance of the Keswick Dam releases to the mass balance calculation and the high degree of variability in metal concentrations that can be expected under varying storm and SCDD operational conditions, this approach would not be appropriate for SCDD operations. If this approach were to be relied upon, a very conservative estimate of the average metal content would be necessary to assure that the SBPS are attained (while lacking sufficient actual data).

Data Availability

Data as close to "real time" as possible in each storm event are required to assure efficient and accurate operation of the SCDD releases. Historic data can assist in the evaluation of the chemical and physical processes occurring during a storm event.

The time required to collect and analyze samples limits the ability of the operator to define the metal concentrations in these releases during storm events, when high variability would be expected. The cost associated with an aggressive program (for example, hourly samples with 2- to 4-hour analytical turn-around time) would be very high.

SMC acquired hourly data during the January 1995 storm. (SMC has identified QA/QC concerns with this data set.) EPA acquired data at 4-hour intervals during daytime hours in its 1996 field precipitation study. Each of these efforts required significant dedicated manpower for the duration of the sampling event. Fast turn-around time on analysis of the samples would require a dedicated laboratory staff. The sampling and lab efforts would each require staffing around the clock.

The water quality of these releases was observed to be highly variable. Laboratory turn-around time, even as short as 2 to 4 hours, would be expected to introduce significant uncertainty with respect to the actual conditions at the time that SCDD operational decisions must be made.

EPA currently acquires water quality data regarding the Keswick Reservoir releases on a frequency of once per week during the wet season with daily or twice daily sampling during specific storm events. The USBR implements a similar program. Any significant expansion of this sampling and analytical program would be expected to introduce significant additional costs.

The IMM data base contains a significant amount of dissolved copper and zinc data for the Keswick Dam releases over the period of EPA's IMM Superfund cleanup action.

The USBR has the capability to analyze the water quality samples locally.

Characteristics

Figure B-21 depicts the dissolved copper concentration in the Keswick Dam releases during the early January 1995 storm. The measured values indicate significant variability from hour to hour.

Figure B-22 depicts the hardness of the Keswick Dam releases during the early January 1995 storm. The measured values indicate significant variability from hour to hour. The protective SBPS would vary with the observed hardness.

Figure B-23 depicts the pH of the Keswick Dam releases during the early January 1995 storm. The measured values indicate that large releases of the low pH IMM-contaminated water of the Spring Creek watershed result in a significant depression of the pH of the Sacramento River.

Figure B-24 depicts the dissolved copper concentration in the Keswick Dam releases during the March 1995 storm. The measured values indicate significant variability from hour to hour.

Issues and Concerns

The measurement and reporting uncertainty associated with the Keswick Dam release water quality is an extremely important factor for the overall Keswick Reservoir mass balance. Uncertainty associated with the Keswick Dam release metal concentrations translates directly to uncertainty in the calculated mass balance and allowable SCDD release rate.

There is uncertainty whether the sampling location beneath Keswick Dam allows for taking representative dissolved copper and zinc concentrations experienced in the Sacramento River. During storms, sideflow may dilute the Sacramento River waters at the point at which it is being sampled.

EPA's sensitivity analyses show that a 1 ppb difference in the reported water quality at this station could result in a significant difference in the calculated allowable SCDD release under certain situations.

Acquiring hourly data to define conditions in the Sacramento River during storm events is technically feasible, but would be costly. For example, in January 1995, SMC performed such a sampling effort and contracted with a local laboratory to analyze the samples. Analyses were generally available within 2 to 4 hours from the time the sample was taken. Because of cost, this type of effort may not be practicable for a routine monitoring to support SCDD operational decision making.

Analytical capability to accurately measure metal concentrations at the levels present in Shasta Dam releases requires a very high level of quality assurance.

Documents in the IMM Administrative Record indicate that limitations inherent in current analytical techniques may produce results that are uncertain by as much as 0.2 to 0.3 ppb copper. Relative to the Shasta Dam releases, this may be as much as 10 to 30 percent of the actual sample value, but in comparison to the protective SBPS, this error would be approximately 3.6 to 5.4 percent. This analytical limitation introduces an additional small uncertainty into the mass balance analysis for these waters.

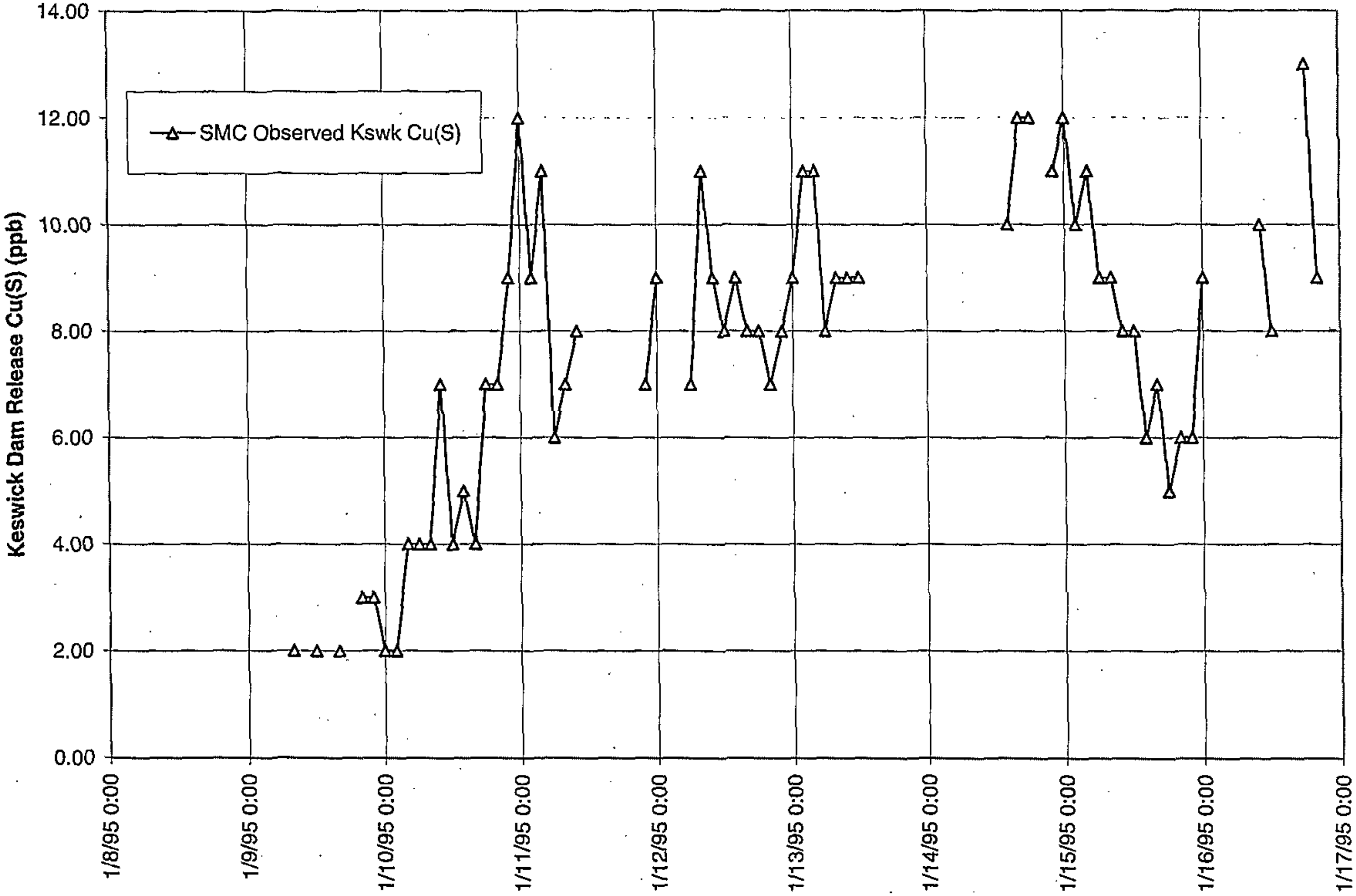

FIGURE B-21
KESWICK DAM DISSOLVED COPPER
IRON MOUNTAIN MINE, REDDING, CALIFORNIA

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Early January 1995 Storm

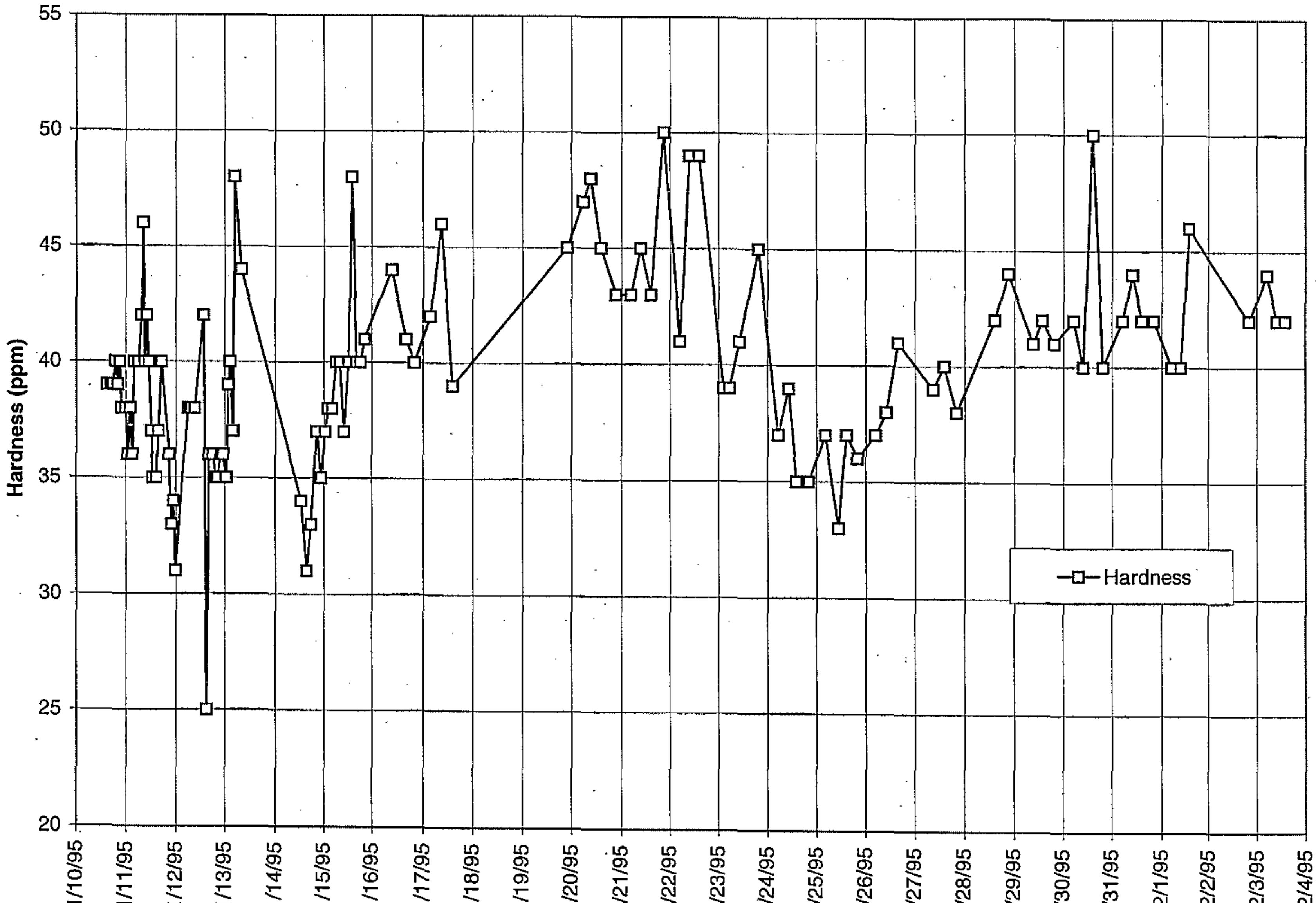

FIGURE B-22
HARDNESS
IRON MOUNTAIN MINE, REDDING, CALIFORNIA

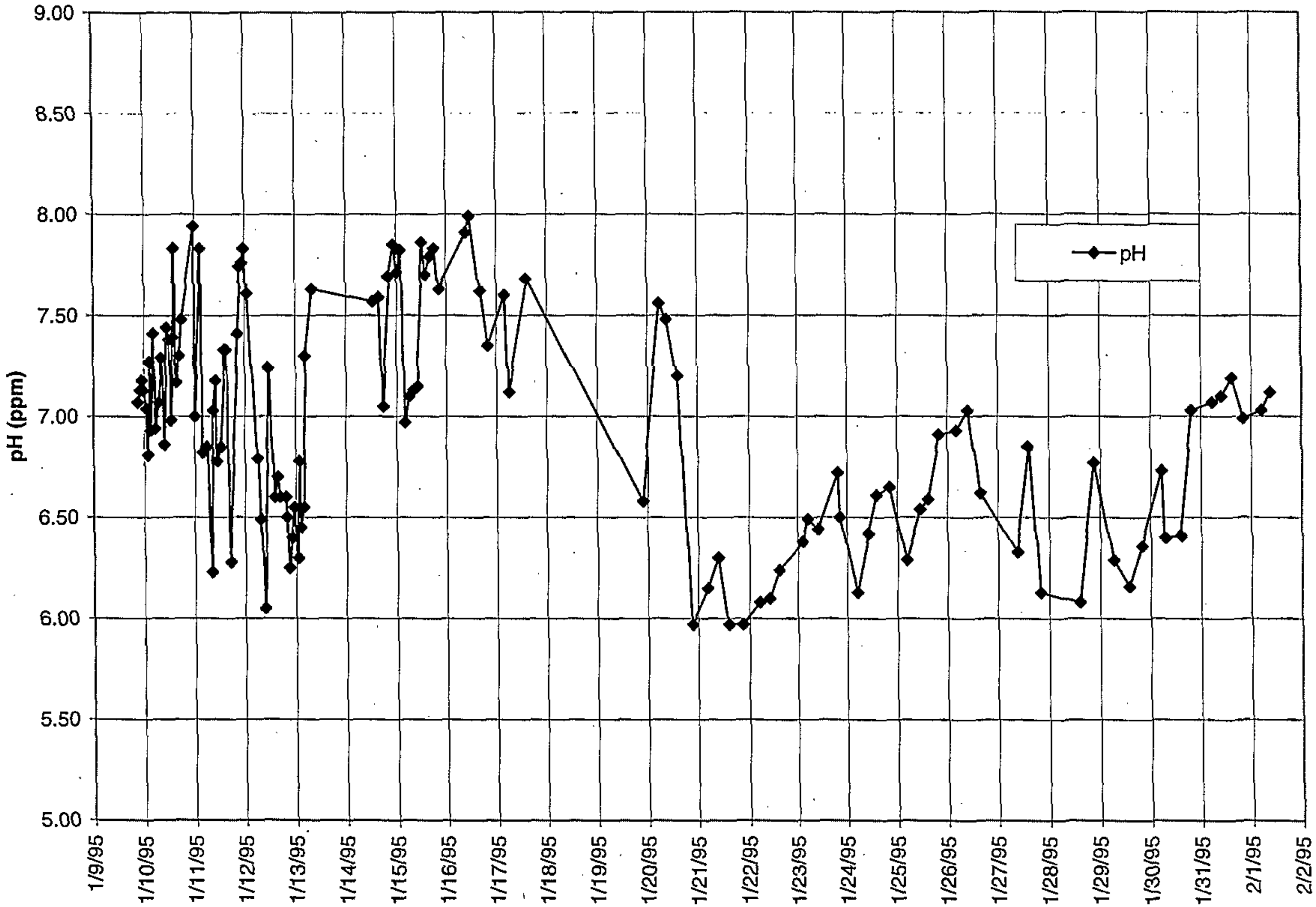

FIGURE B-23
pH
IRON MOUNTAIN MINE, REDDING, CALIFORNIA

9/29/97
187h_ph.xlsChart2

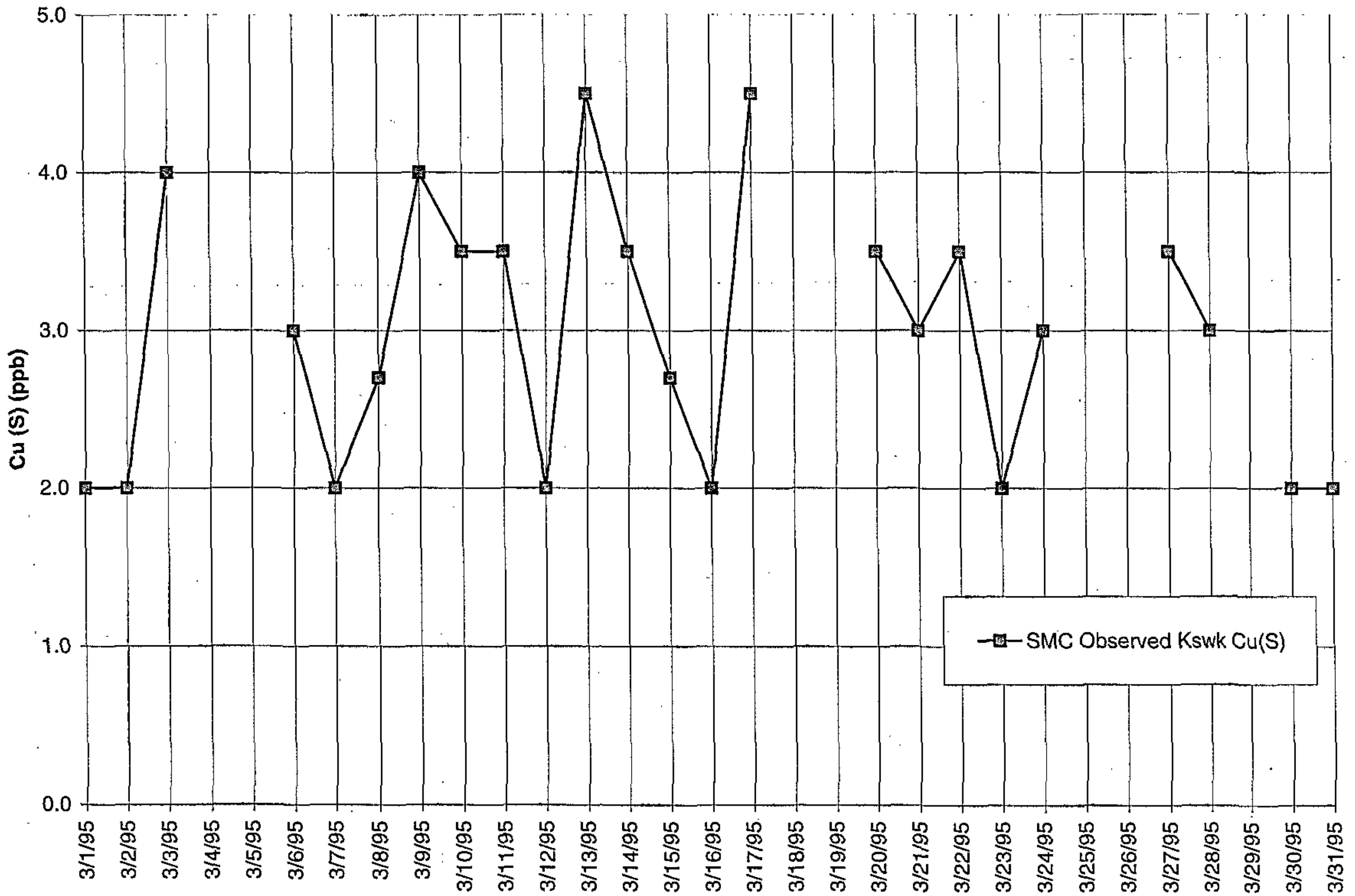

FIGURE B-24
KESWICK DAM RELEASE
COPPER CONCENTRATION
IRON MOUNTAIN MINE, REDDING, CALIFORNIA

EPA has performed a sensitivity analysis to assess the many uncertainties involved in a Keswick Reservoir mass balance calculation. These analyses support the conclusion that data uncertainties are an important consideration in the interpretation of the mass balance results.

Spring Creek Debris Dam Outlet Release

The SCDD outlet release is the primary controlled variable in operations of CVP facilities at Keswick Reservoir to assure dilution of the IMM contaminant discharges to safe levels. The Keswick Reservoir mass balance is performed to calculate the allowable SCDD outlet release rate based upon all other known CVP facility operational factors.

The SCDD outlet release can generally be characterized as very low to moderate volume releases with high metal concentrations.

The SCDD releases, which contain the IMM metal discharges, are generally the most significant metal input of the Keswick Reservoir mass balance.

Release rates from the SCDD outlet works can be accurately measured.

The water quality of these concentrated metal discharges can readily be monitored, but vary significantly during storm inflows to the SCR.

Once EPA's Superfund remedy has been fully implemented, SCDD spillway discharges should not occur, except under infrequent circumstances. SCDD spillway discharges can generally be characterized as low to moderate volume releases with high metal concentrations.

Spring Creek Debris Dam Outlet Release Flowrates

SCDD outlet release rates can be determined by (1) measurement with the SCDD weir, and (2) calculation based upon changes in SCR elevation and known operational settings.

Data Availability

Flowrates of SCDD releases can be accurately measured at the weir below the SCDD outlet at the time that water quality samples are taken.

Bi-hourly USBR operations data are not widely reported, but are available in an electronic database. The USBR has relied on this detailed record to make operational decisions regarding CVP facilities related to Keswick Reservoir during past major storm events. The bi-hourly operations data provide a detailed record of SCDD outlet release operations for those circumstances during which detailed records are necessary to assure an accurate record operational changes made more frequently than on a daily basis, and the profile of a spillway discharge (uncontrolled release).

USBR CVP daily operations summary reports are much more widely available than the Bureau's bi-hourly data. The release rates reported by the USBR in its operations summary are values as of 12:00 midnight on the reporting day. These release rates provide information that can be relied upon to estimate the "daily average" flowrate of SCDD outlet releases. This approach is more reliable during periods of stable operation than during highly variable operations during storm periods.

Characteristics

The metal load associated with the SCDD outlet release is generally the dominant metal load to Keswick Reservoir. Figure B-25 indicates that the SCDD outlet release copper load was approximately 90 percent of the entire copper load discharged into Keswick Reservoir during the early January 1995 storm.

SCDD outlet release rates are controlled to meet the calculated allowable release rate based upon the performance of the Keswick Reservoir mass balance, considering the amount of metal that would be expected to precipitate from dissolved to particulate form.

Because of the complex nature of the chemical and physical interactions of the SCDD releases with the SCPH releases, Keswick Reservoir accretion flows, and Shasta Dam releases, the calculation of the allowable SCDD release is uncertain, and a margin of safety must be provided to assure that the SCDD releases do not cause an exceedance of the protective SBPS.

Issues and Concerns

Uncertainty associated with the measurement and reporting of SCDD outlet release rates is a very significant factor for the overall Keswick Reservoir mass balance for all storm periods. The metal loads from the SCDD outlet releases dominate the Keswick Reservoir mass balance. Any reporting or measurement error would significantly alter the calculated mass balance and metal precipitation rates.

Flowrates for the outlet weir can be reliably measured, and the SCDD spillway discharges can be accurately estimated from recorded water surface elevations.

The bi-hourly operations data provide a detailed record of SCDD outlet release operations for those circumstances during which operational changes are made more frequently than daily, and during spill situations (uncontrolled releases).

The release rates reported by the USBR in its operations summary are instantaneous values as of about 12:00 midnight on the reporting day.

The USBR operational summary is currently maintained for USBR record keeping and operational decision making requirements. It is not intended for use as engineering information of the sort needed for the performance of the Keswick Reservoir mass balance. Future reliance on such an operational record for engineering data to be input into the Keswick Reservoir mass balance requires that the accuracy and precision of the operational record to be assured through quality control and quality assurance procedures for the record keeping.

Spring Creek Debris Dam Outlet Release Water Quality

SCDD outlet release water quality can be readily monitored, but is expected to vary significantly throughout storm periods.

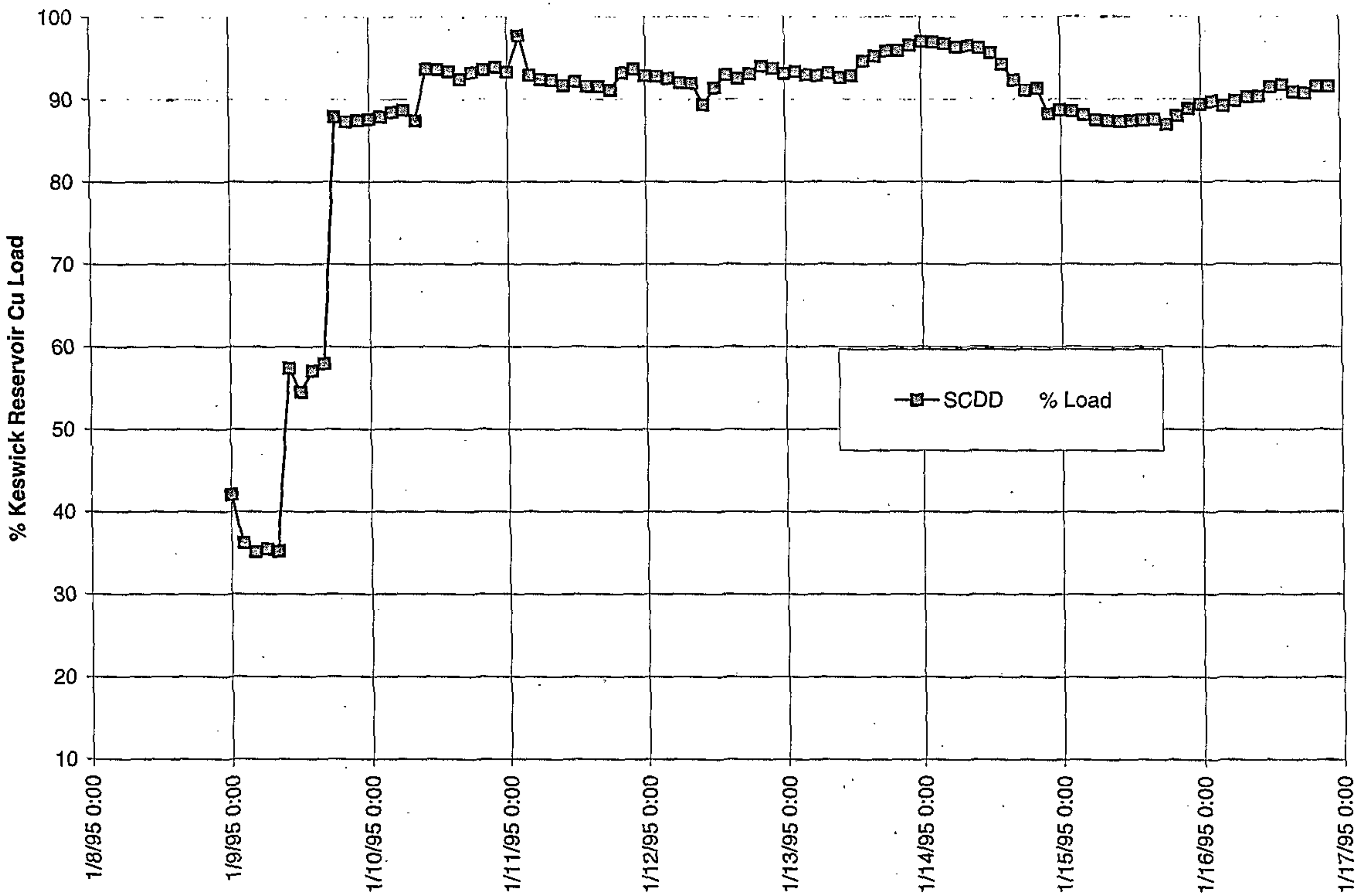

FIGURE B-25
SCDD RELEASE WITH SCDD PERCENT KESWICK RESERVOIR COPPER LOAD
IRON MOUNTAIN MINE, REDDING, CALIFORNIA

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Early January 1995 Storm

SCDD outlet release water quality is an important factor with respect to managing SCDD releases of IMM metals under controlled release conditions to meet the protective State Basin Plan Standards (SBPS). The measured quality of the SCDD outlet releases is an important component of the equation in calculating metal precipitation rates in Keswick Reservoir.

The preferred approach would be to acquire "real time" water quality data to characterize the SCDD outlet releases. However, analytical techniques are not available to allow for "real time" analysis of copper, zinc, and hardness.

The second best approach would be to analyze a representative water quality sample as soon as practicable. However, the time delay associated with the performance of field sampling and the water quality analysis turn-around time is a significant factor in assuring "real time" water management operations to safely dilute the IMM metal discharges. Performing frequent sampling and expediting analysis of the sample would enhance operation efficiency. Frequent sampling and expediting analysis of the sample would significantly increase the associated cost.

A third approach, relying on a historic data set to characterize the SCDD outlet release, is not appropriate for SCDD operational purposes. Because of the importance of the SCDD metal load to the Keswick Reservoir mass balance calculation and the high degree of variability in metal concentrations that can be expected under varying storm and SCDD operational conditions, this approach would not be appropriate for SCDD operations. If this approach were employed, it would be necessary to rely on a very conservative estimate of the average SCDD outlet release metal content to assure that the SBPS are attained while lacking actual data.

Data Availability

Data as close to "real time" as possible in each storm event are required to assure efficient and accurate operation of the SCDD releases. Historic data and storm specific data regarding SCR inflow water quality and stratification can assist in the evaluation of the chemical and physical processes occurring during a storm event.

The time required to collect and analyze samples limits the ability of the operator to define the metal concentrations in these releases during storm events, when high variability would be expected. The cost associated with an aggressive program (for example hourly samples with 2- to 4-hour analytical turn-around time) would be very high.

SMC acquired hourly data during the January 1995 storm. (SMC has identified QA/QC concerns with this data set.) EPA acquired data at 4-hour intervals during daytime hours in its 1996 field precipitation study. Each of these efforts required significant dedicated manpower for the duration of the sampling event. Fast turn-around time on analysis of the samples would require a dedicated laboratory staff. The sampling and lab efforts would each require staffing around the clock.

The water quality of these releases was observed to be highly variable. Laboratory turn-around time, even as short as 2 to 4 hours, would be expected to introduce significant uncertainty with respect to the actual conditions at the time that SCDD operational decisions must be made.

EPA currently acquires water quality data regarding the SCDD outlet releases on a frequency of once per week during the wet season with daily or twice daily sampling during specific storm events. The USBR implements a similar program. Any significant expansion of this sampling and analytical program would be expected to introduce significant additional costs for staff and laboratory support.

The IMM database contains dissolved copper and zinc data for the SCDD outlet releases over the period of EPA's Superfund cleanup action. These data indicate the significant degree of variability in metal concentrations associated with the inflows to SCR during storm periods and over the course of a series of storms.

Historic data reflect the progress of EPA's IMM cleanup actions. Data in the IMM database indicate that metal concentrations in SCR inflows are significantly cleaner than prior to EPA's cleanup.

The USBR has the capability to analyze the water quality samples locally.

Characteristics

Figure B-26 depicts the peak nature of the IMM-contaminated inflows to SCR with the dissolved copper concentration of the inflows. This figure depicts the variability of copper concentrations during the early January 1995 storm period.

Figure B-27 depicts the peak nature of the IMM-contaminated inflows to SCR with the closely correlated peak nature of the copper loads during the early January 1995 storm period.

Figures B-28 and B-29 depict the relationship between the IMM metal discharges from Boulder Creek (BCMO) and Slickrock Creek (SRMO) with surface water flow during the 1995-1996 wet season. These figures also show the variability of the IMM discharge with the "first flush," or first major surface runoff event of the wet season.

Figure B-30 depicts the peak nature of the IMM-contaminated inflows to SCR with the dissolved copper concentration of the inflows. This figure depicts the variability of copper concentrations during the March 1995 storm period.

Figure B-31 depicts the peak nature of the IMM-contaminated inflows to SCR with the closely correlated peak nature of the copper loads during the March 1995 storm period.

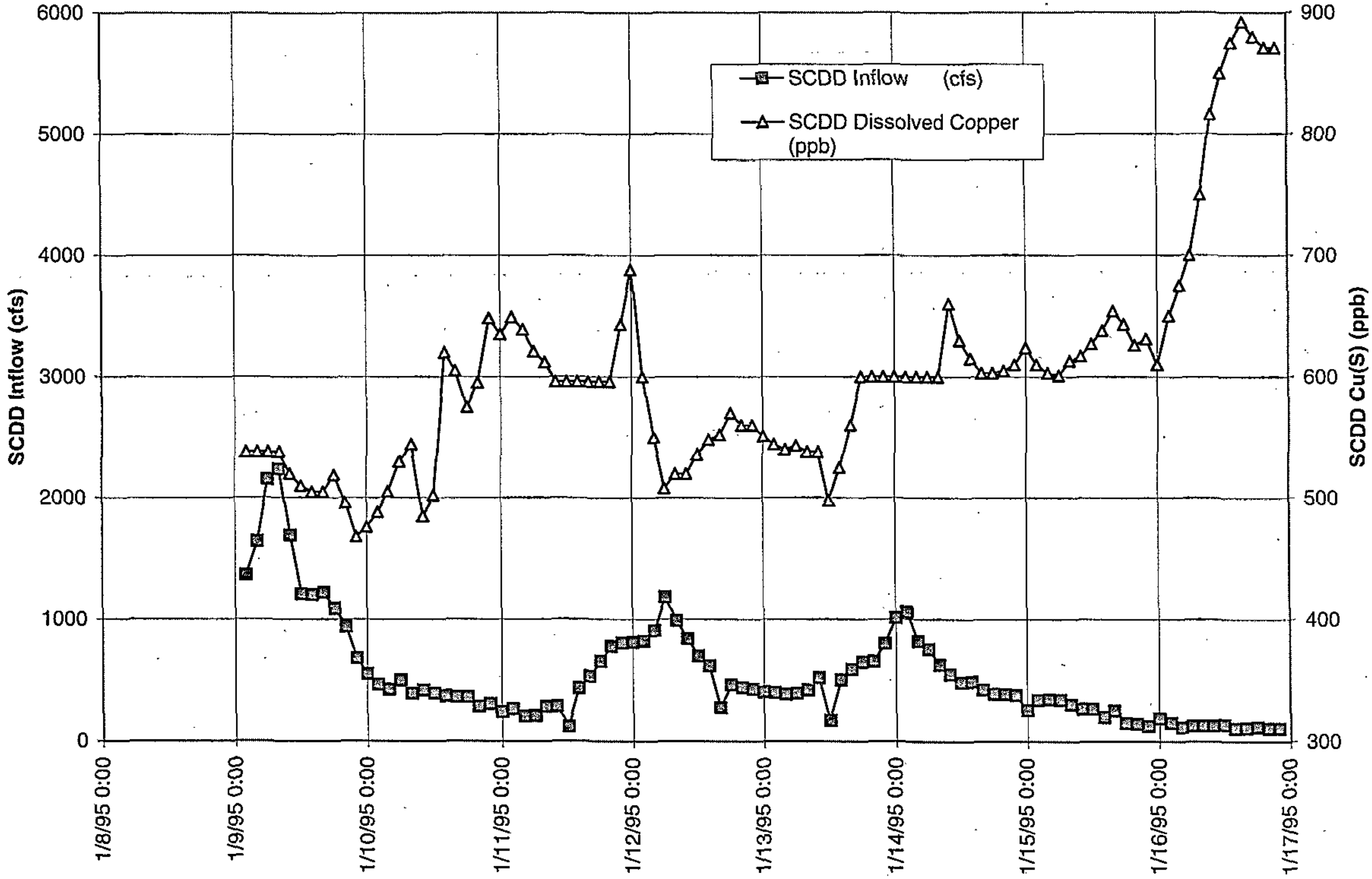

FIGURE B-26
SCCD INFLOW AND SCDD RELEASE DISSOLVED COPPER CONCENTRATION
IRON MOUNTAIN MINE, REDDING, CALIFORNIA

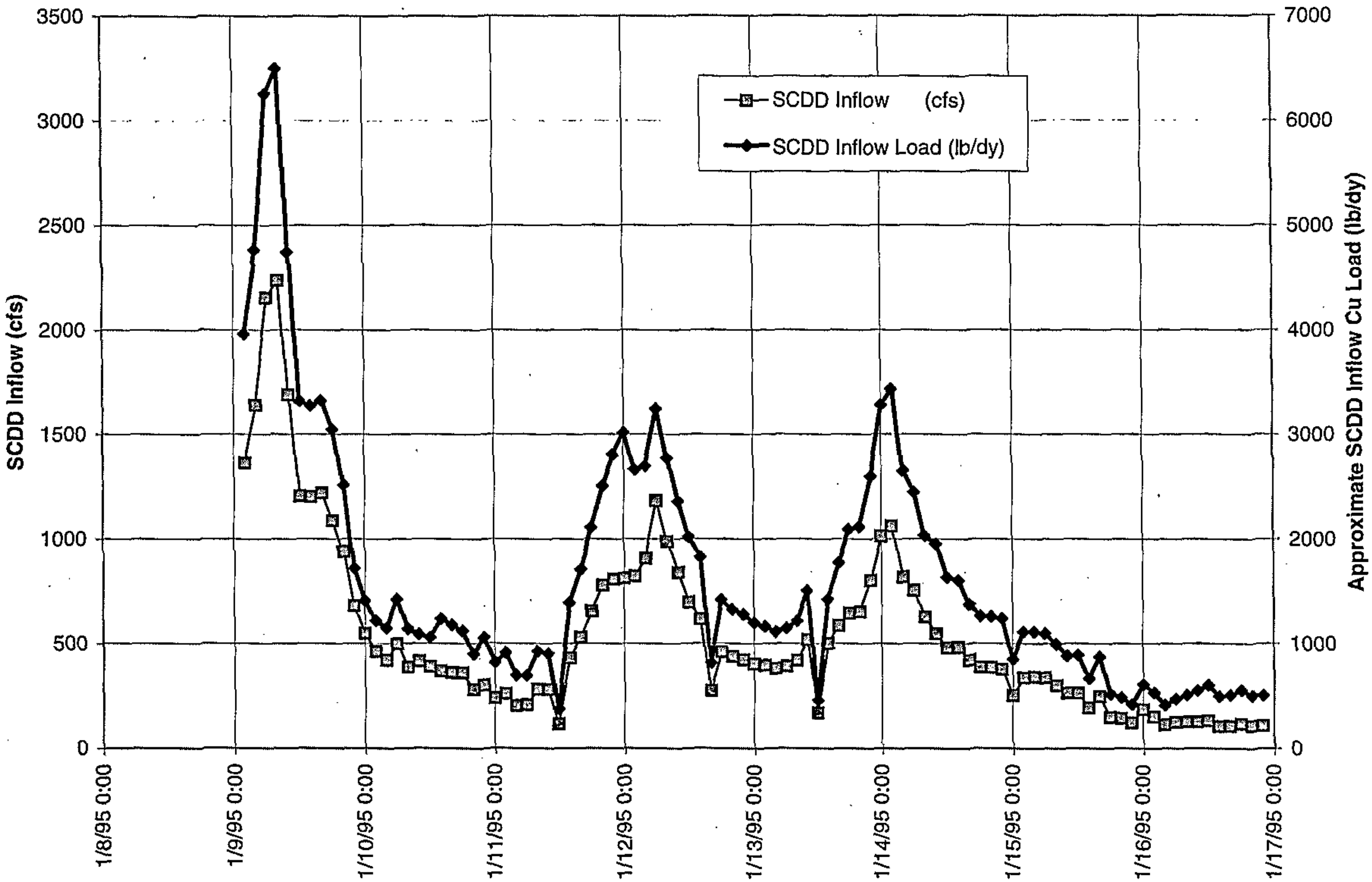

FIGURE B-27
SCCD INFLOW AND SCDD INFLOW COPPER LOAD
IRON MOUNTAIN MINE, REDDING, CALIFORNIA

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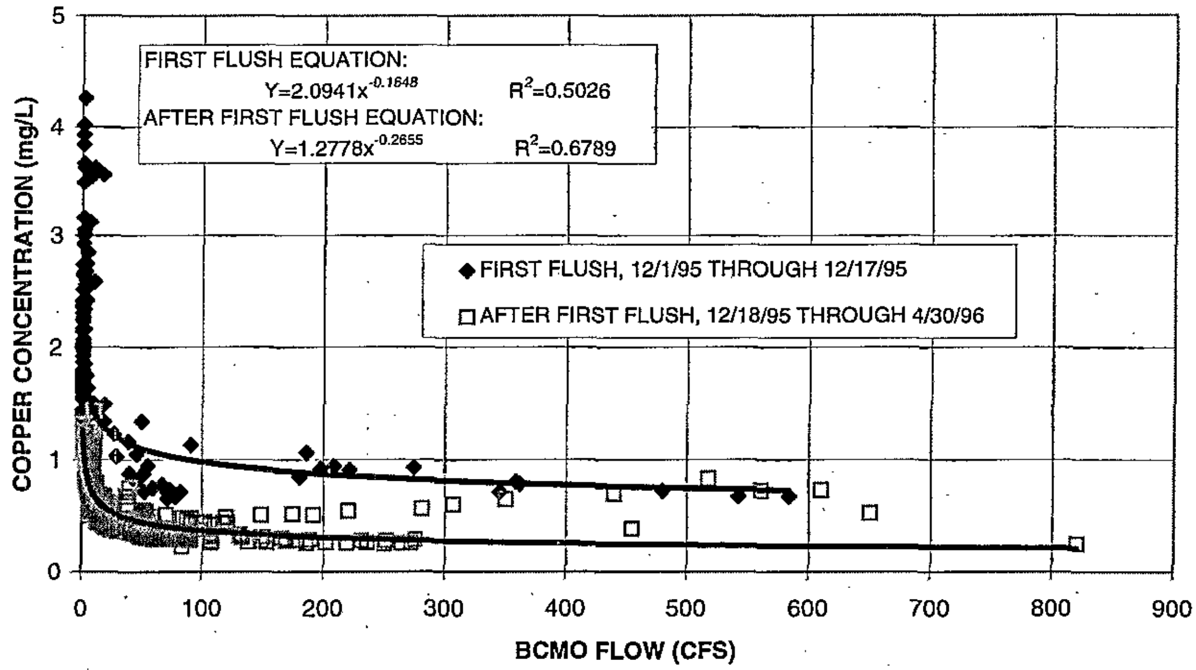
Early January 1995 Storm



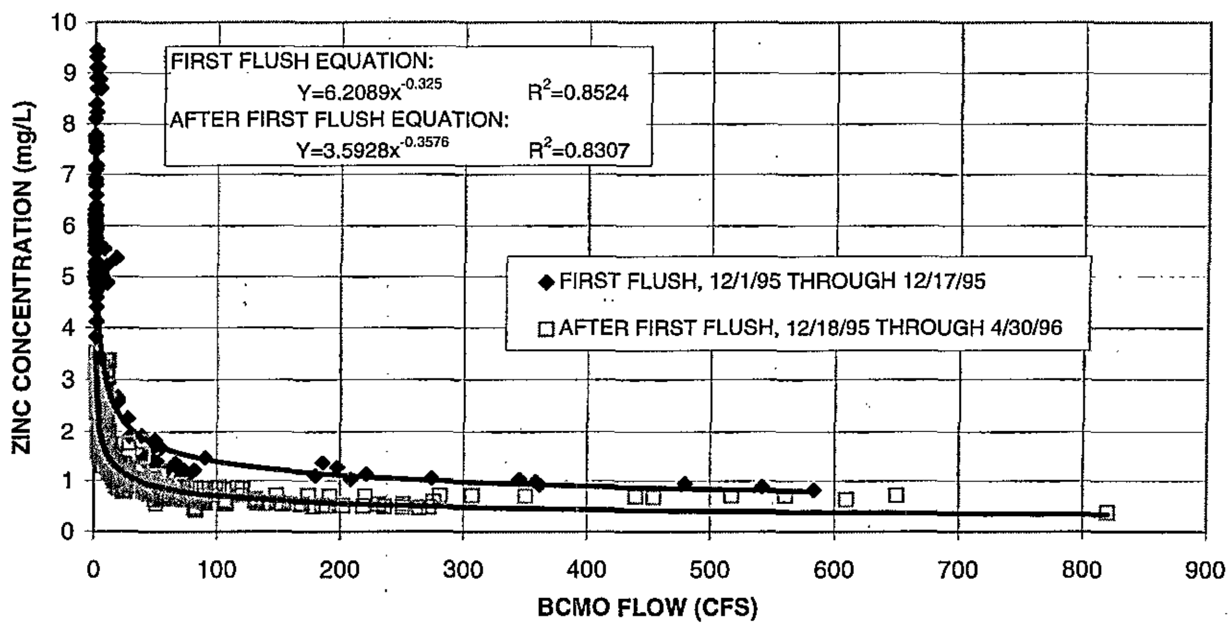


FIGURE B-28
CONCENTRATION-FLOW REGRESSION EQUATIONS OF 1995-1996 BCMO DATA
IRON MOUNTAIN MINE, REDDING, CALIFORNIA

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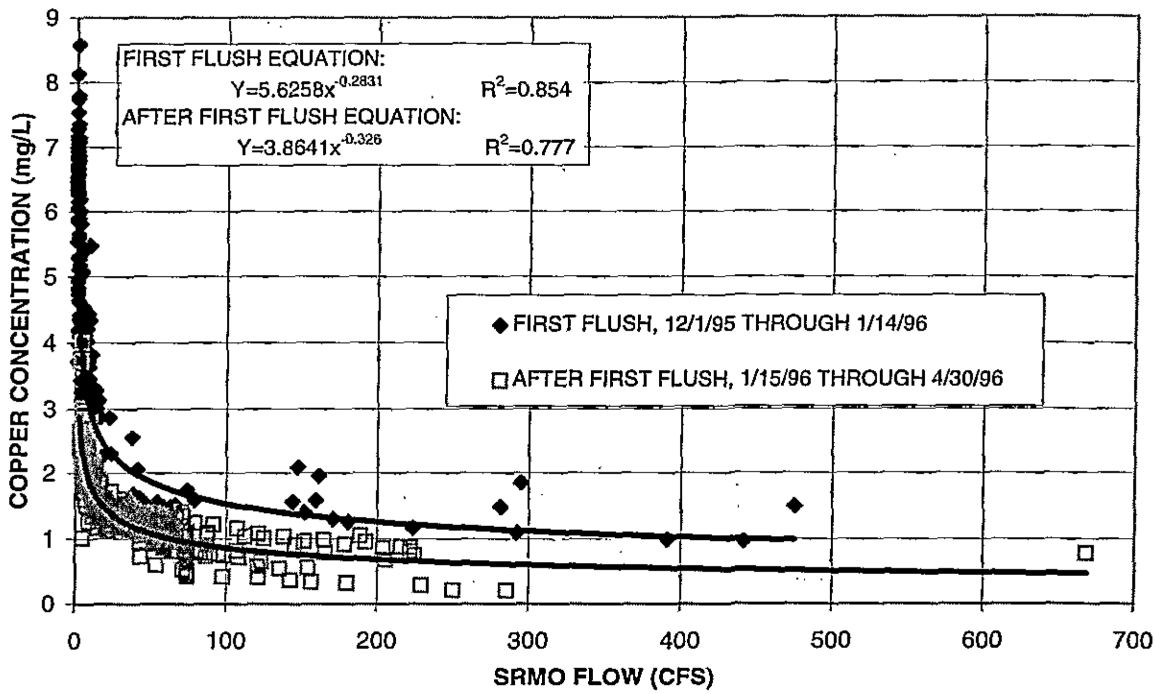

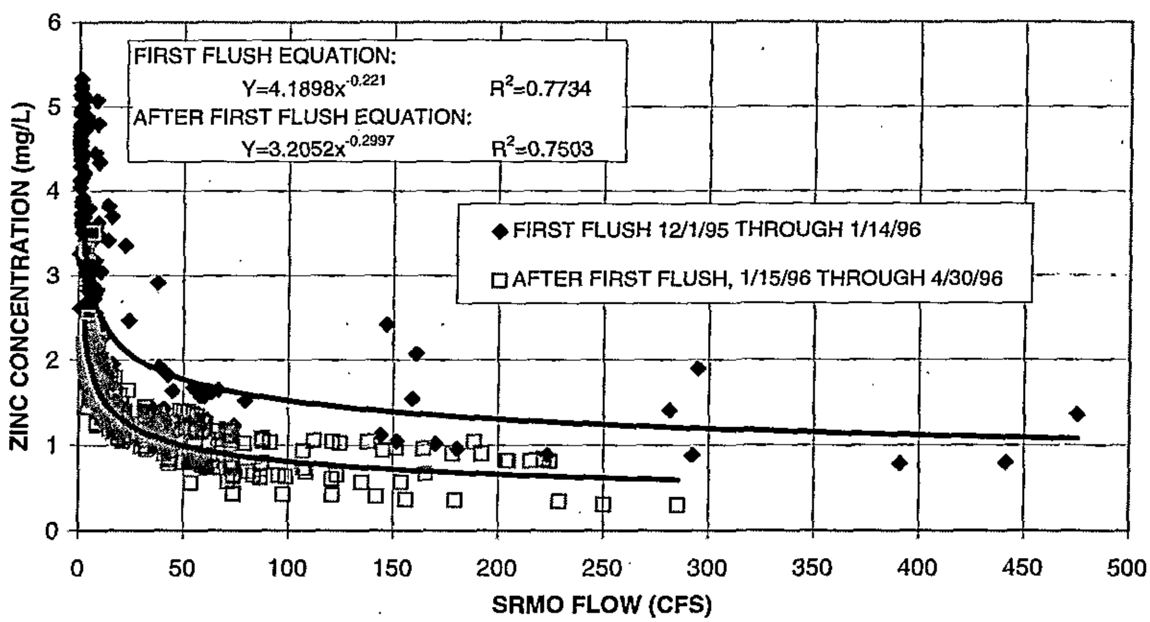

FIGURE B-29
CONCENTRATION-FLOW REGRESSION EQUATIONS OF 1995-1996 SRMO DATA
IRON MOUNTAIN MINE, REDDING, CALIFORNIA

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SR CU&ZN187_eq.xls

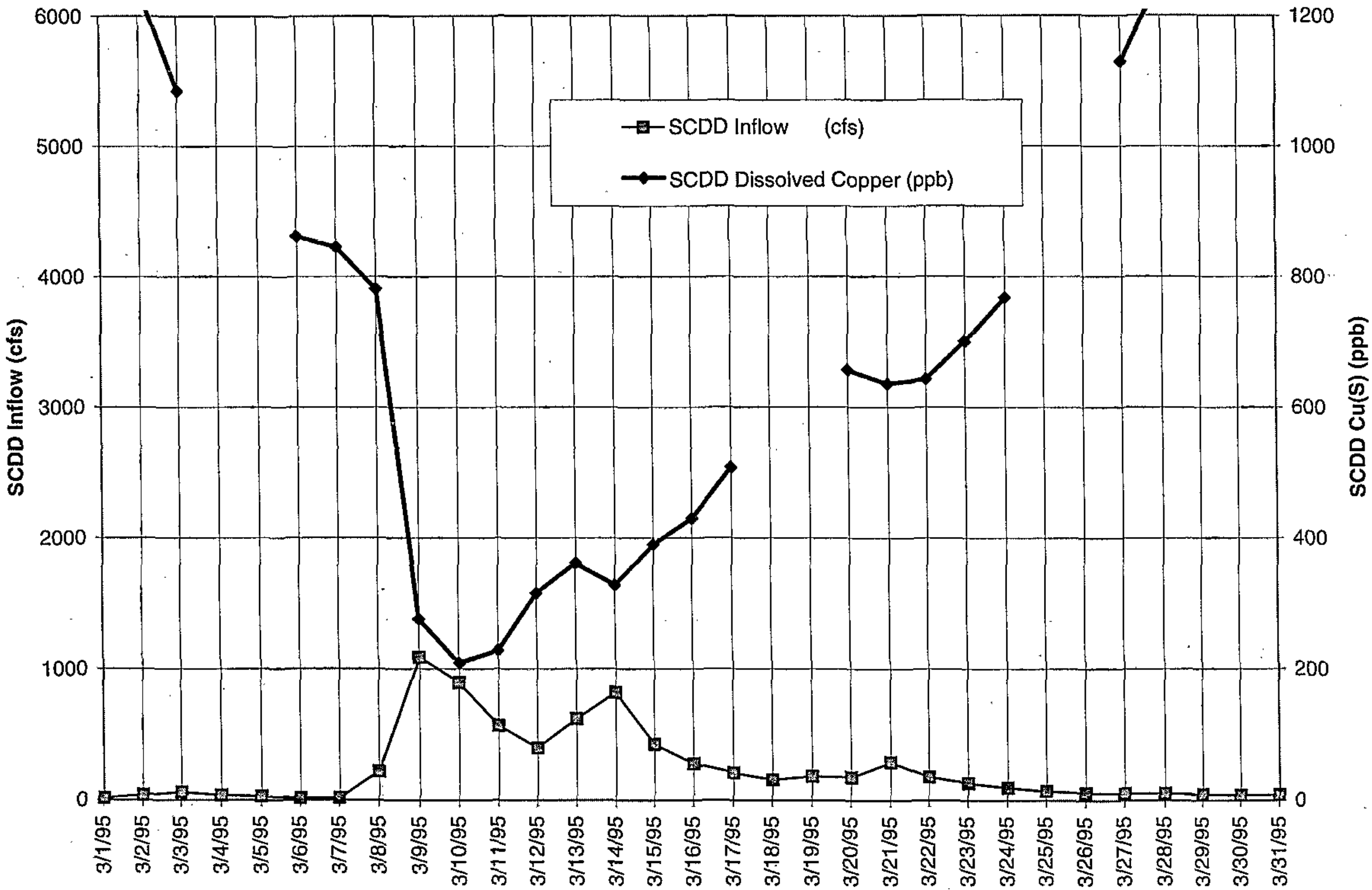

FIGURE B-30
SCDD RELEASE DISOLVED COPPER CONCENTRATION WITH SCDD INFLOW
IRON MOUNTAIN MINE, REDDING, CALIFORNIA

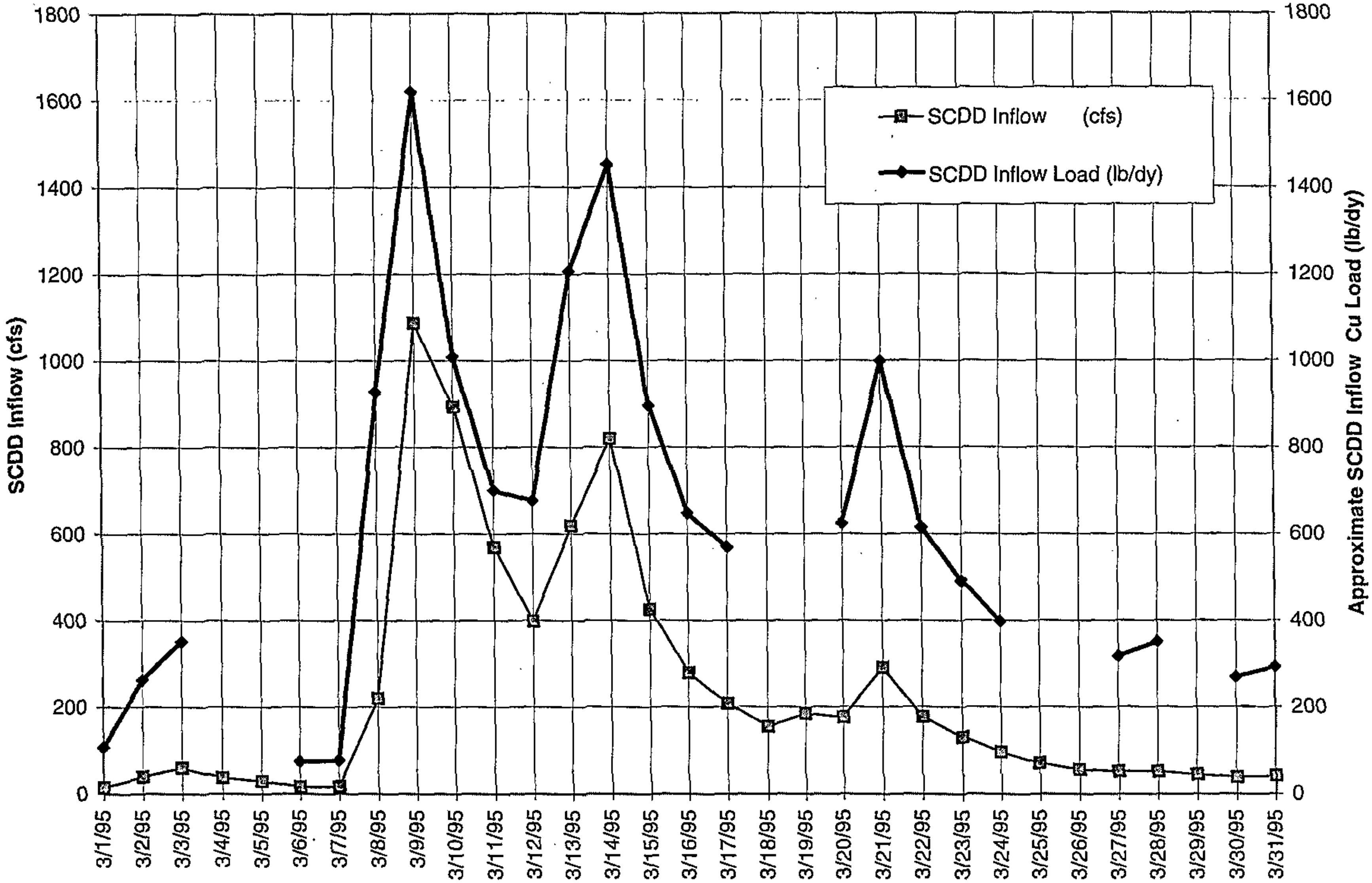

FIGURE B-31
SCDD INFLOW AND SCDD INFLOW COPPER LOAD
IRON MOUNTAIN MINE, REDDING, CALIFORNIA

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IN THE UNITED STATES DISTRICT COURT FOR THE EASTERN DISTRICT OF CALIFORNIA

UNITED STATES OF AMERICA, Plaintiff/Counterclaim-Defendant and and Third-Party Defendant, v. IRON MOUNTAIN MINES, INC., et al., T.W. ARMAN, and RHONE-POULENC BASIC CHEMICALS CO., Defendants/Counterclaim-Plaintiffs and Third-Party Plaintiffs	Civil Action No. S-91-768 DFL/JFM
STATE OF CALIFORNIA, Plaintiff/Counterclaim-Defendant and Third-Party Defendant, v. IRON MOUNTAIN MINES, INC., T.W. ARMAN, and RHONE-POULENC BASIC CHEMICALS CO., Defendants/Counterclaim-Plaintiffs and Third-Party Plaintiffs.	Civil Action No. S-91-1167 DFL/JFM **DECLARATION OF PAUL FUJITANI** Date: August 29, 1997 Time: T.B.A. Judge: Hon. David F. Levi Courtroom No. 3

/ / /

I, Paul Fujitani, declare as follows:

1. I am employed by the Bureau of Reclamation ("USBR") as a hydraulic engineer. I have worked for USBR for approximately 14 years, and have experience in the following divisions: approximately 6 years in the Division of Design and Construction, approximately 1 year in the Division of Water and Power Resources Management, and, most recently, approximately 7 years in the Central Valley Operations Office ("CVO").

2. As a hydraulic engineer in the CVO in Sacramento, California, I am currently responsible for monitoring and directing the operations of the Trinity River Division, Sacramento River Division, and Shasta Division of the Central Valley Project ("CVP"). These divisions of the CVP include the following facilities: Trinity Dam, Clair Engle Reservoir, Trinity Powerplant, Lewiston Dam and Reservoir, Lewiston Powerplant, Buckhorn Dam, J.F. Carr Powerplant, Whiskeytown Dam and Lake, Spring Creek Powerplant, Spring Creek Debris Dam ("SCDD") and Reservoir, Shasta Dam and Reservoir, Keswick Dam and Reservoir, Shasta Powerplant, Keswick Powerplant, Red Bluff Diversion Dam, and the Tehama-Colusa Canal and Corning Canal.

3. Decisions concerning operations of the Sacramento River Division, Trinity River Division, and Shasta Division, like all other divisions, are governed by a series of federal laws, regulations, directives, water rights, contracts, and agreements. Many of these regulatory constraints are listed in Figure 2 of the Central Valley Project Operations Criteria and Plan ("CVP-OCAP"). <u>See</u> CVP-OCAP at 3-4 (copy attached hereto as Exhibit "A"). Since publication of the CVP-OCAP, Congress enacted the

Central Valley Project Improvement Act ("CVPIA") in 1992. The CVPIA modified Congress's three-tiered system of CVP priorities. The first tier maintains navigation, flood control and river regulation as the highest priorities. The second tier, previously limited to irrigation and domestic uses, now also includes fish and wildlife mitigation, protection and restoration. The third tier consists of power generation and, now fish and wildlife enhancement. USBR's operation of the CVP is governed by this congressionally mandated order of priorities. Biological Opinions concerning specific aquatic species in the Sacramento River and in the Sacramento-San Joaquin Bay-Delta have also been issued since 1992.

4. In addition to the limitations imposed by law, there are significant physical constraints on the operation of the CVP. Each component of the CVP has unique physical characteristics, such as, size, storage capacity, spillway design, and structural composition, among other things. In addition, each component has a different watershed area that varies geographically. For example, precipitation and runoff in each watershed can vary significantly in intensity, duration, and timing. These physical parameters are considered when making operational decisions.

5. As a result of these legal and physical constraints, CVP operations require constant discretionary decision-making by the responsible federal officials and USBR's CVO personnel.

6. Water quality problems caused by acid mine drainage from Spring Creek into Keswick Reservoir and the Sacramento River are a major concern to CVP operations, as evidenced, for example, by the section of the CVP-OCAP dedicated to describing the special

considerations USBR takes into account in administering Shasta Division facilities. See CVP-OCAP at 43-45. SCDD was constructed as a remedial design to reduce the impact on the Sacramento River of sediment and toxic drainage emanating from Iron Mountain Mine ("IMM"). SCDD operations are coordinated with water releases from Shasta Dam and Whiskeytown Reservoir (through Spring Creek Powerplant) so as to minimize the impact of the toxic mine drainage on aquatic life in the Sacramento River. USBR has had to adjust operations of the Northern CVP due to special considerations posed by SCDD operations and the impacts of Spring Creek.

Under routine operations, USBR attempts to maintain Spring Creek Reservoir at a minimum target storage capacity (currently the target elevation is approximately 707 feet above sea level). Water quality sampling is performed by USBR in the Northern California Area Office in accordance with the 1980 Memorandum of Understanding between the State of California and USBR, or as needed for operational decisions. SCDD operational data is monitored on a "real time" basis - meaning that storage, release, and inflow conditions are normally monitored remotely via telemetry every 2 hours. Data may also be accessed on approximately 10 minute intervals when more detailed monitoring is desired. Typical operations of the SCDD will vary between the Winter, when there is usually a large amount of precipitation, and the Summer, when it is much drier. During the wetter months, operating SCDD to meet target reservoir elevations and Sacramento River water quality objectives is difficult and requires increased attention and the exercise of discretion.

7. The coordination of releases from the various components of the CVP is a complex process that involves a great deal of discretion under constantly changing conditions. In performing my duties, I am authorized to make significant decisions regarding the releases from the components of the Sacramento River, Shasta, and Trinity River Divisions and coordination with other divisions of the CVP. In doing so, I am required to weigh the risks and benefits of each decision and their potential effect on public health and safety, flood operations, and other vital concerns. For example, an evaluation of the forecasted air temperatures may indicate a need for an increased release from Keswick Reservoir in order to protect the winter-run salmon. First, CVO has to determine whether the additional water would come out of Clair Engle Reservoir or Shasta Reservoir. Then the impacts of the increased water flow on the State of California's Oroville Reservoir release and USBR's Folsom Reservoir release would have to be evaluated. The change in Keswick Reservoir releases would affect operating conditions as far as 250 river miles away in the Sacramento-San Joaquin Delta and could result in either the State Department of Water Resources ("DWR") or USBR pumping additional water out of the Delta to compensate for the increased flow from Keswick. Changes in inflow to the Delta and pumping out of the Delta can affect the Delta fishery. Changes in the Delta pumping will, in turn, affect the available water supply in the San Joaquin Valley and Southern California. Each operational decision is also made pursuant to the requirements of the laws, regulations, directives, water rights, contracts, and agreements which govern the operation of the CVP. Operations are

evaluated on both a short-term daily basis and on a long-term basis to meet the CVP objectives.

8. At times, USBR has voluntarily released water from Shasta Dam or Whiskeytown Dam (through Spring Creek Powerplant) to dilute SCDD releases. The decision to release water must be balanced between many competing needs. For example, other environmental factors include conserving cold water for future releases for certain fish species, preventing encroaching salinity in the Delta, and maintaining water supply for wildlife preserves and refuges and instream fishery flows.

9. The Spring Creek Powerplant is also operated so as to have a minimum impact on any hazardous substances released from IMM which have come to be located in Keswick Reservoir. A constant minimum flow of clean water imported through the Spring Creek Tunnel is routinely released through the powerplant whenever water is released from SCDD, even when minimal power benefits are obtained. This operational regimen was implemented by USBR in approximately 1990 to provide some flushing of the powerplant tailrace and the Spring Creek Arm of Keswick to prevent SCDD releases from accumulating in the Spring Creek Arm and to prevent or minimize any slugging of IMM sediments into the Sacramento River when the powerplant is brought back on line for peaking power generation. If Keswick Reservoir is at a low elevation, releases from Shasta Dam and Spring Creek Powerplant are coordinated in order to minimize the potential to resuspend sediment in Keswick Reservoir. SCDD releases are coordinated with water releases from Shasta Dam and Spring Creek Powerplant to minimize the harmful impacts of IMM's toxic mine drainage.

10. A recent example of the complexity of these discretionary operational decisions can be seen in a review of the flood control operations earlier this year. In December 1996/January 1997, the Northern California region was inundated with record levels of precipitation brought by a series of storm systems. The first heavy storm came on December 28, 1996, depositing 2 to 2.5 inches of rain over Northern and Central California. See New Year's Flood of 1997, A Summary of the Operations of the U.S. Bureau of Reclamation Central Valley Project During California's Record Flood, ("1997 Flood") at 3 (attached hereto as Exhibit "B"). The second storm brought 2 to 4 inches of rain to the mountains and the third storm, arriving December 31, 1996, and January 1, 1997, brought near record levels of rainfall. For example, Brandy Creek on the upper Sacramento River had 10.3 inches, Stouts Meadow in the Shasta drainage had 9.2 inches, and Taylor Ridge in the Trinity River watershed had 8.2 inches. Id. The storm totals included 25 inches in the Feather River Basin and the Shasta drainage received over 23.7 inches at Shasta Dam and 36.39 inches at Stouts Meadow. Id. at 4; and map on page 5 (illustrating the geographic relationship of several CVP reservoirs).

In response to the forecasted weather systems, CVO went into 24-hour operations on December 28, 1996. The operations personnel worked in teams of 2-4 hydraulic engineers per each of the three designated shifts. The shifts overlapped in order for the outgoing shift to brief in-coming personnel on the existing Sacramento River and reservoir conditions.

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At 10 a.m. the National Weather Service ("NWS") held the first of up to three daily briefings, providing weather/rainfall projections, as well as reservoir inflow hydrographs which were essential to plan daily operations. In addition, USBR monitored data from numerous rain and stream flow gauges to evaluate the actual rainfall/inflows and update the NWS projections. Other federal, State, and local agencies participated in the daily briefings, including the personnel from the Army Corps of Engineers ("ACOE"), State Water Project ("SWP"), DWR Division of Flood Management (lead agency for the "flood fight" program to protect cities), State Office of Emergency Services, and representatives from local and private flood control projects.

Depending on the weather, rainfall, inflow, flooding conditions, and projections, decisions would be made as to where to release, store, hold, or divert water flows. USBR might, for example, be asked to hold releases from certain reservoirs to allow a city (e.g. Meridian) to install sandbags to prevent further flood damage. After the briefing on the Sacramento and San Joaquin Rivers and their reservoirs, a conference call briefing was held with operators of all major reservoirs on the San Joaquin River. This included operators from throughout the San Joaquin Valley, as well as, ACOE, USBR, and the State Division of Flood Management. USBR further coordinated with Sacramento Area Flood Control Agency ("SAFCA") engineers on releases from Folsom Dam on the American River, State Office of Emergency Services (disaster centers), local governments and law enforcement. The joint State-Federal Flood Operations Center 24 hour shift operations continued until January 18, 1997.

Even after the flood emergency subsided, USBR engaged in considerable coordination to allow drainage and cleanup of the flood damage. For example, USBR was asked to keep releases from Shasta Dam at a reduced level so that dikes could be breached and lands drained.

I declare pursuant to 28 U.S.C. § 1746 that the foregoing is true and accurate.

Dated: 5/30/97

Paul Fujitani

Paul Fujitani

Figure 2. Laws, Directives, and Orders Affecting Central Valley Project (CVP) Operation

Law or Directive	Year	Effect on CVP
Reclamation Act	1902	Formed legal basis for subsequent authorization of the CVP.
Rivers and Harbors Act	1935 1937 1940	First authorization of CVP for construction and provision that dams and reservoirs used first for rivers' regulation, improvement of navigation, and flood control. Second for irrigation and domestic users; third for power.
Reclamation Project Act	1939	Provided for the repayment of the construction charges and authorized the sale of CVP water to municipalities and other public corporations and agencies, plant investment, for certain irrigation water deliveries to leased lands.
Water Service Contracts	1944	Provided for the delivery of specific quantities of irrigation and municipal and industrial water to contractors.
Flood Control Act	1944	Authorized flood control operations for Shasta, Folsom, and New Melones Dams.
Water Rights Settlement Contracts	1950	Provided diverters holding riparian and senior appropriative rights on the Sacramento and American Rivers with CVP water to supplement water which historically would have been diverted from natural flows.
Grasslands Development Act	1954	Added authority for use of CVP water for fish and wildlife purposes. Also authorized development of works in cooperation with the State for furnishing water to Grasslands for waterfowl conservation.
Trinity River Act	1955	Provided that the operation of the Trinity River Division be integrated and coordinated with operation of other CVP features to allow for the preservation and propagation of fish and wildlife.
Reclamation Project Act	1956	Provided a right of renewal of long-term contracts for agricultural contractors for a term not to exceed 40 years.
Fish and Wildlife Coordination Act	1958	Provided for integration of Fish and Wildlife Conservation programs with Federal water resources developments; authorized Secretary of the Interior to include facilities to mitigate CVP-induced damages to fish and wildlife resources. Required consultation with the U.S. Fish and Wildlife Service.
San Luis Authorization Act	1960	Authorized San Luis Unit and provided for financial participation of Reclamation in development of recreation.
Reclamation Project Act	1963	Provided a right of renewal of long-term contracts for municipal and industrial contractors.
Auburn-Folsom South Unit Authorization Act	1965	Authorized Auburn-Folsom South Unit. Provided for financial participation of Reclamation in development of recreation.

Figure 2. Laws, Directives, and Orders Affecting Central Valley Project (CVP) Operation (continued)

Law or Directive	Year	Effect on CVP
Power Contract 2948A	1967	Provided banking agreements with the Pacific Gas and Electric Company of California (PG&E), under which excess CVP energy and capacity is sold to the PG&E. The PG&E in return delivers power to CVP customers. Contract now administered by the Western Area Power Administration.
National Environmental Policy Act (NEPA)	1969	Established policy, set goals, and provided means for ensuring scientific analysis, expert agency participation and public scrutiny and input are incorporated into the decisionmaking process regarding the actions of the Federal agencies.
Council on Environmental Quality Regulations	1970	Provided directives for compliance with NEPA.
State Water Resources Control Board Decision 1379	1971	Established Delta water quality standards to be met by both the CVP and the State Water Resources Project (SWP).
Endangered Species Act	1973	Provided protection for animal and plant species that are currently in danger of extinction (endangered) and those that may become so in the foreseeable future (threatened).
State Water Resources Control Board Decision 1485	1978	Ordered the CVP (and the SWP) to guarantee certain conditions for water quality protection for agricultural, municipal and industrial, and fish and wildlife use.
Secretarial Decision on Trinity River Release	1981	Allocated CVP yield so that releases can be maintained at 340,000 acre-feet in normal water years, 220,000 acre-feet in dry years, and 140,000 acre-feet in critically dry years.
	Amended 1991	Released a minimum of 340,000 acre-feet annually for each dry or wetter water year. During each critically dry water year, 340,000 acre-feet will be released if at all possible.
Corps of Engineers Flood Control Manuals for: Shasta Folsom New Melones	 1977 1959 1980	Prescribed regulations for flood control.
Corps of Engineers Flood Control Diagram for: Shasta Folsom New Melones	 1977 1986 1982	Outlined descriptions and data on flood potential and flood ratings.
Reclamation Reform Act	1982	Introduced the concept of full-cost pricing, including interest on the unpaid pumping plant investment, for certain irrigation water deliveries to leased lands.

Figure 2. Laws, Directives, and Orders Affecting Central Valley Project (CVP) Operation (continued)

Law or Directive	Year	Effect on CVP
Coordinated Operating Agreement (COA)	1986	Agreement between the U.S. government and the State of California. Determined the respective water supplies of the CVP and the SWP while allowing for a negotiated sharing of Sacramento-San Joaquin Delta excess outflows and the satisfaction of in-basin obligations between the two projects.
Public Law 99-546	1986	Ensures repayment of plant-in-service costs at the end of FY 1980, by end of FY 2030.
Public Law 99-546	1986	DOI and Reclamation directed to include total costs of water and distributing and servicing it in CVP contracts (both capital and O&M costs).
WR 90-5, 91-1	1990 1991	Water Rights Orders that modified Reclamation water rights to incorporate temperature control objectives in Upper Sacramento River.
National Marine Fisheries Service Biological Opinion	1992	Established operation under the Reasonable Prudent Alternative (RPA) for 1992 operations to protect winter run. Provided for "incidental taking" within the RPA.

be developed, which is useful both in anticipating future encroachment problems and in analyzing receding flood control conditions.

Navigation and Related "Depth and Head" Issues of the Sacramento River

Navigation is an expressly authorized function of Shasta and Keswick Dams. The River and Harbors Acts of August 30, 1935, and August 26, 1937, authorized funds for expenditure in accordance with plans set forth in the Rivers and Harbors Committee Document Number 35, 73rd Congress. Document Number 35 recommended providing channel depths of 6 feet between Sacramento and Colusa and 5 feet between Colusa and Chico Landing (see previous figure 2), and a minimum flow of 5,000 ft^3/s between Chico Landing and Sacramento. Section 7 of the Flood Control Act of December 22, 1944, provides that it is the duty of the Secretary of War to prescribe regulations for the use of storage allocated for flood control or navigation at all reservoirs constructed wholly or in part with Federal funds. The COE now has this responsibility. In 1952, it was decided not to allocate storage space in Shasta Lake to navigation and that Section 7 would not apply to navigational features. Although the COE is, therefore, without authority to regulate Shasta operations for navigation, the River and Harbors Act of 1937 and subsequent acts obligated Reclamation to operate Shasta Dam to improve navigation.

Recently, no commercial traffic occurs between Sacramento and Chico Landing, and, therefore, the COE has not dredged this reach to preserve channel depths since 1972. Because no detrimental consequences occur to navigational interests, Reclamation does not operate to provide a minimum flow of 5,000 ft^3/s at all points below Chico Landing. However, Shasta and Keswick Dams are operated to provide a minimum flow of 5,000 ft^3/s at Wilkins Slough in all but extremely dry years.

The navigation requirement of a minimum flow of 5,000 ft^3/s has been used as the basis for designing many of the pumping stations along the Sacramento River. At flows below 5,000 ft^3/s, diverters have reported increased pump cavitation as well as greater pumping head requirements. Diverters are able to operate for extended periods at flows as low as 4,000 ft^3/s at Wilkins Slough, but pumping operations become severely affected, and some pumps become inoperable at flows lower than this. On a daily operating basis, flows may drop as low as 3,500 ft^3/s for short periods while changes are made in Keswick releases to reach target levels at Wilkins Slough, but using the 3,500 ft^3/s rate as a target level for an extended period would have major impacts on diverters.

No criteria have been established that specifies when the flow criteria will be relaxed. However, the basis for Reclamation's decision to operate at less than 5,000 ft^3/s is the increased importance of conserving water in storage when water supplies are not sufficient to meet full contractual delivery and other operational requirements.

Water Quality Problems Caused by Spring Creek

Water quality problems caused by acid mine drainage from Spring Creek into Keswick reservoir and the Sacramento River are a major concern to CVP operations. In the Spring

Creek watershed, concentrated acid mine water from several inactive copper mines and leaching from exposed ore bodies and tailing piles have caused fishkills in the Sacramento River below Keswick Dam. Operating Spring Creek Debris Dam and Shasta Dam with dilution criteria has allowed some control of the toxic wastes, but in January 1980, Reclamation, DFG, and SWRCB executed a Memorandum of Understanding (MOU) to implement actions to further protect the Sacramento River system from heavy metal pollution from Spring Creek and adjacent watersheds. The MOU identifies actions and responsibilities for each agency and established release criteria based on allowable concentrations of total copper and zinc in the Sacramento River below Keswick Dam. The release criteria are summarized below:

- The Iron Mountain Mine area above Spring Creek Debris Dam is currently undergoing cleanup operations as part of the Environmental Protection Agency Superfund. Part of this cleanup includes diverting inflows to Spring Creek Debris Dam that flow through the Iron Mountain Mine drainage around the drainage directly into Keswick Reservoir. This results in the inflow into the debris dam being reduced; however, metal concentrations in the inflow may be higher than in previous years. In general, the equations developed for the MOU are only used as a basis for releases. If the threat of a hazardous waste spill is not imminent, releases are generally set at a reduced percentage of the allowable according to the MOU equations. As monitoring data become available, this percentage is adjusted up or down as needed to meet the requirements below Keswick Dam.

- When Spring Creek Reservoir storage exceeds 5,000 acre-feet, the MOU provides for "emergency" relaxation amounting to a 50-percent increase in the specified objective concentrations of copper and zinc. Recently, Reclamation and the DFG have agreed not to use the emergency criteria until a spill actually occurs.

Under the provisions of the MOU, Reclamation agrees to operate according to the above-mentioned criteria and schedules, provided that such operation will not cause flood control parameters on the Sacramento River to be exceeded or interfere unreasonably with other CVP requirements (as determined by Reclamation). The MOU also specified a minimum schedule for monitoring copper and zinc concentrations at Spring Creek Debris Dam and in the Sacramento River below Keswick Dam. Reclamation has primary responsibility for this monitoring, although DFG and the Regional Water Quality Control Board (RWQCB) also collect and analyze samples as needed. After a multilevel intake structure at the debris dam was installed, the monitoring schedule specified in the MOU was modified to sample a minimum of once weekly, regardless of the elevation in the dam.

To minimize the buildup of metal concentrations in the water in the Spring Creek arm of Keswick Reservoir, releases from the debris dam need to be coordinated with releases from Spring Creek Powerplant to keep the arm of the powerplant flushed out. This coordination is not always possible when Spring Creek Powerplant may not be scheduled to operate. During these periods, Spring Creek may be operated at "Speed No Load" (SNL) to meet electrical system needs. Running the units at SNL requires small amounts of water and provides some flushing of the Spring Creek arm. The number of hours the units at Spring Creek Powerplant may be operated according to this method depend on electrical system needs and the availability of water for release to Spring Creek Powerplant. If releases are made from the debris dam but Spring Creek Powerplant has not operated recently and power generation is scheduled, the units at the Spring Creek Powerplant generally will be run for several hours at SNL before they begin generating. This is done to minimize the slugging effect that might occur if the units at Spring Creek Powerplant were instantly brought to full load. When power generation from Spring Creek Powerplant is needed for electrical system emergencies, it may not be possible to operate the units at SNL before generating.

Operating Spring Creek Debris Dam during major flood events is complicated because releases from Keswick Dam may be reduced to meet flood control objectives at Bend Bridge just when storage and inflow at Spring Creek Reservoir are high. Because Spring Creek releases may have to be reduced when Keswick releases are reduced to maintain the required dilution of copper and zinc, spills can and have occurred from Spring Creek Reservoir. In these situations, the amount and concentrations of the spill must be considered to calculate the allowable Spring Creek Debris Dam release, and the release from the outlet works must be adjusted accordingly. When spills exceed the allowable release, the Spring Creek Powerplant discharge may be curtailed to confine the toxic water in the Spring Creek arm of Keswick Reservoir until Keswick releases can be increased.

In some cases, Reclamation has voluntarily released additional water from Shasta Lake and/or Spring Creek Powerplant to dilute spills to meet ratios of toxic metals below Keswick Dam. No criteria have been established for making these releases, and the releases therefore have been treated on a case-by-case basis. Since water released for diluting spills is likely to be in excess of any other CVP requirements, these releases risk losing the beneficial use of the water for other purposes.

Seepage and Drainage Problems in the Sacramento River

There has been a long history of concern among farmers over seepage from the Sacramento River to adjacent farmlands. Reclamation has shown in numerous studies that high stages in the river can result in seepage flow under levees. While other factors including flood-plain topography and stratigraphy influence seepage, the height and duration of the river stage above the level of adjacent land are major contributors to the extent and severity of the seepage. Because the operations of Shasta and Keswick Dams do regulate a substantial portion of riverflow, these operations can affect seepage potential. In most years, Shasta Dam operations do provide some degree of seepage control; however, Shasta was not authorized specifically for controlling seepage and the impacts of operations on seepage potential are incidental to authorized CVP purposes.

Widespread seepage damage might be expected to occur in those very wet years when inflow to Shasta Lake exceeds the 90-percentile level, particularly those years that have major flood events late in the season. Because of a large amount of storage space that would have to be reserved for seepage control in these wet years, operation for Shasta Lake for that purpose is

Appendix B

NEW YEAR'S FLOOD OF 1997

A Summary of the Operations of the U.S. Bureau of Reclamation Central Valley Project During California's Record Flood

WATER HOSE FROM THE TROPICS

The only area to receive heavy precipitation on Christmas Day was the Smith River drainage in Del Norte County close to the Oregon border, which got 4.2 inches in the 30 hours ending at 7 a.m. Thursday. However, a new Pacific weather system brought rain in amounts of up to 1 inch to the mountains of both Northern and Central California.

The Feather/Yuba Basin got 3 inches and regions to the south received lesser amounts down to 1.5 inches in the San Joaquin.

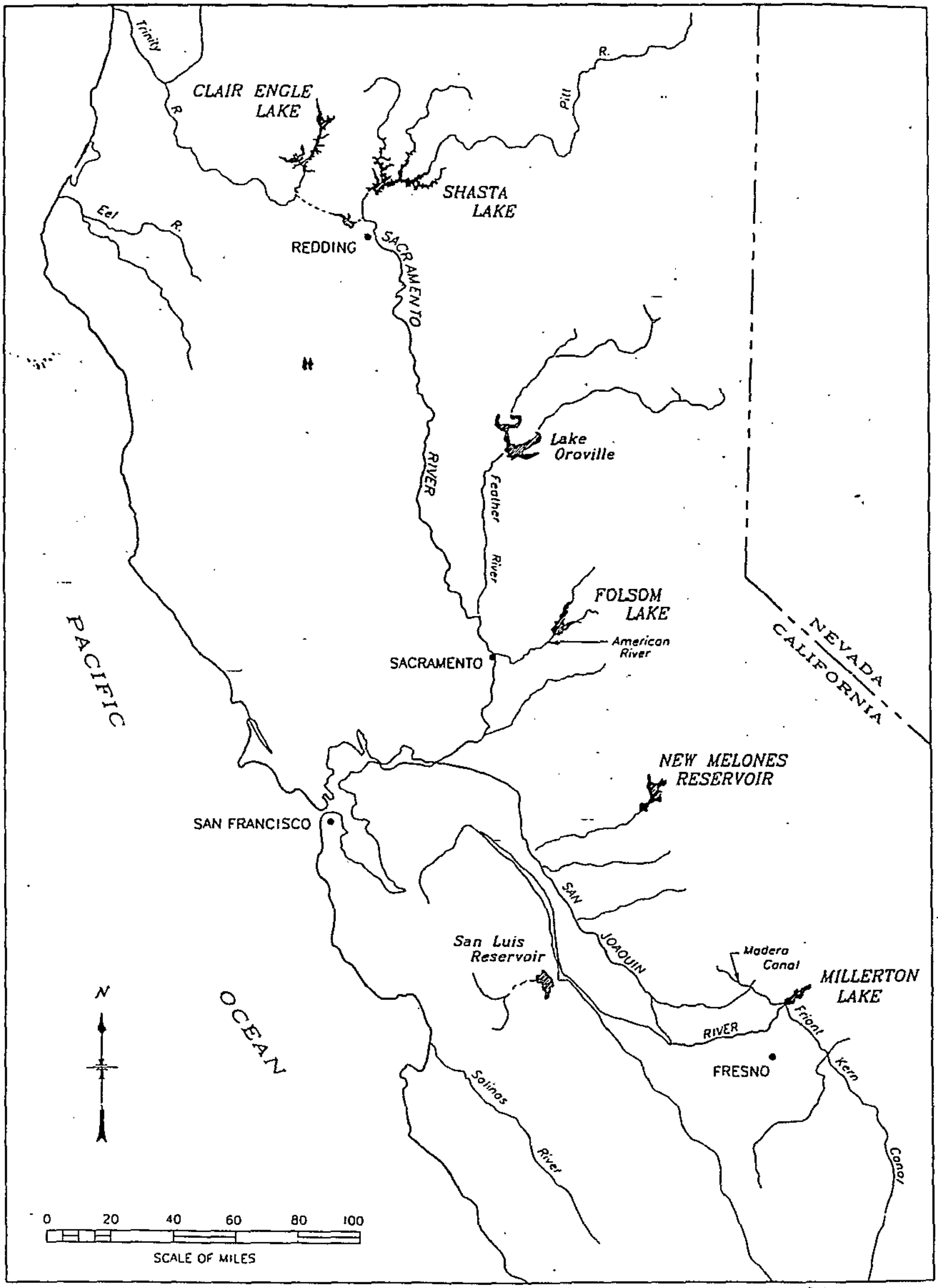
Mork reported that the overall weather pattern setting up for Sunday through Wednesday "has parallels to our historic storms of the century in Northern California" including December 1955, January 1963, December 1964, February 1986, and January/March 1995.

The rain slackened a little on Friday, December 27, but still produced an inch over the north coast and 1 to 2 inches in mountains of Northern California.

The first heavy storm of the subtropical series hit on Saturday, December 28, bringing 2 inches of rain to the Shasta, Feather, and American watersheds as well as the Russian River on the coast. Snow levels remained at 7,000 feet. The first wave was not as heavy as expected but did produce 2 to 2.5 inches over a wide area of Northern and Central California. The second storm in the series brought 2 to 4 inches of rain to the mountains.

A third wave hit Tuesday and into Wednesday, once again bringing precipitation in near-record volumes, including 4.6 inches for the Feather Basin. Individual areas hit high peaks of rainfall like 10.3 inches at Brandy Creek on the upper Sacramento and 9.2 inches at Stouts Meadow, also in the Shasta drainage and 8.2 at Taylor Ridge in the Trinity River watershed. As the storm moved southward, the American River averaged close to 3 inches and the Feather 1.1 inches.

The New Year brought the heaviest wave of all with 6.2 inches in the Feather River Basin raising the flow into Oroville to a peak of 302,000 cfs. The American and Stanislaus drainages averaged more than 5 inches, the San Joaquin 4 inches, and the Kings 3 inches. Blue Canyon in the American had more than 9 inches. The storm had brought a total of 25 inches to the Feather Basin. Other storm totals included 29.73 inches at Blue Canyon, 18.7 at Gianelli and 15.4 at Calaveras Big Trees in the Stanislaus drainage, and 19.29 at Chilkoot Meadows in the San Joaquin. Huntington Lake above Friant Dam on the San Joaquin got nearly 7 inches in 2 days. Inflow to New Melones reservoir on the Stanislaus peaked at 84,857 cfs on January 2. The San Joaquin surged to levels that would peak at a record 95,040 in the early hours of January 3. In the Shasta drainage, 23.7 inches fell at Shasta Dam and 36.39 at Stouts Meadow. The inflow to Shasta Lake peaked at 236,734 cfs, which exceeded the 1974 record by 21,000 cfs. Blue Canyon's 24-hour record rainfall of 9.57 inches for the period ending at 4 a.m. on January 2 sent water pouring into Folsom Reservoir at a record peak of 252,538 cfs, virtually identical to the February 1986 flood. The 1-day volume exceeded the previous record of December 1955 by 32 percent.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SCALE OF MILES

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IN THE UNITED STATES DISTRICT COURT FOR THE EASTERN DISTRICT OF CALIFORNIA

UNITED STATES OF AMERICA, Plaintiff/Counterclaim-Defendant and Third-Party Defendant, v. IRON MOUNTAIN MINES, INC., et al., T.W. ARMAN, and RHONE-POULENC BASIC CHEMICALS CO., Defendants/Counterclaim-Plaintiffs and Third-Party Plaintiffs	Civil Action No. S-91-768 DFL/JFM
STATE OF CALIFORNIA, Plaintiff/Counterclaim-Defendant and Third-Party Defendant, v. IRON MOUNTAIN MINES, INC., T.W. ARMAN, and RHONE-POULENC BASIC CHEMICALS CO., Defendants/Counterclaim-Plaintiffs and Third-Party Plaintiffs.	Civil Action No. S-91-1167 DFL/JFM **DECLARATION OF LOWELL PLOSS** Date: August 29, 1997 Time: T.B.A. Judge: Hon. David F. Levi Courtroom No. 3

/ / /

I, Lowell Ploss, declare as follows:

1. I am employed by the United States Bureau of Reclamation ("USBR") as the Operations Manager of the Central Valley Operations office ("CVO"). I assumed this position in March of 1993. Prior to my position as Operations Manager, I held the position of Field Superintendent, Willows Field Office, Central Valley Project ("CVP"), (later titled as the Construction Engineer, Willows Construction Office). I was employed in this position for a period of eight years, serving as the USBR representative in the Sacramento Valley and directing matters of water operations and maintenance for CVP facilities in the Sacramento Valley. Before that, I held several other technical and managerial positions within USBR on matters of water operations and facility maintenance. I have a total of 28 years experience working for USBR.

2. As Operations Manager, I am responsible for providing managerial direction and control over the water and power operations of the CVP in the CVO, located in Sacramento, California. I have personal knowledge of USBR's operation of the CVP, of long-term policy and planning, and of implementation of new and existing legislation and agreements.

3. My responsibilities include the interpretation of policy directives given by upper management in both USBR, specifically and the Department of Interior, generally . In addition, I am responsible for the implementation of those policies through long-term planning and in day-to-day CVP operations. Long-term planning includes making institutional decisions necessary to incorporate statutory provisions into the day-to-day operations.

4. Decisions concerning the development and operations of the CVP are affected by a number of statutes, agreements, directives, contracts and orders. Figure 2 in the Long-Term Central Valley Project Operations Criteria and Plan ("CVP-OCAP"), October 1992, lists many of these statutes, agreements, directives, contracts and orders that impose limitations, obligations and constraints on the operation of the CVP. The CVP-OCAP also describes operations of the CVP and the application of guidelines, policies, and procedures in effect as of 1992. See CVP-OCAP at 2-4 (copy of relevant portions attached hereto as Exhibit "A"; full text of the CVP-OCAP is included with the United States' exhibits as US Ex. 47). The CVP is operated in accordance with these legal authorities.

5. In the statutes authorizing the construction, operation and maintenance of the various divisions of the CVP, Congress has consistently included language directing the Secretary of the Department of Interior, through USBR, to operate the CVP as a single, integrated project. See CVP-OCAP at 1 (Exhibit "A").

6. From its Sacramento offices, the CVO controls water distribution from north of Redding to as far south as Los Banos.

7. In the central and southern portions of the CVP, the State of California and USBR share and operate joint-use facilities. These facilities include: the B.F. Sisk San Luis Dam and San Luis Reservoir, Dos Amigos Pumping Plant, Los Banos and Little Panoche Detention dams and Reservoirs, O'Neill Dam and Forebay, the San Luis Canal, and the William R. Gianelli Pumping-Generating Plant.

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8. In my position as CVO Operations Manager, I am directly involved in USBR's coordination with Federal, State, and local authorities. Decisions relating to the coordination of CVP operations with these entities entails an evaluation of the proposed operations under guidance, policy and directives established by USBR. I am familiar with the relevant reference documents, policy guidance, and legal requirements and refer to them when evaluating any proposed coordinating agreement or decision.

9. As CVO Operations Manager, I oversee the operations at the CVO. As a result, I have broad responsibilities for the operations of the CVP, a project that encompasses a complex geographic region subject to constantly changing weather and water supplies.. My duties are varied and complex and are dictated by specific facts as they develop, requiring the exercise of my judgment as I implement USBR policies. During the course of exercising my duties, I review guidelines, policies, and procedures established by USBR. I routinely solicit advice and information from other agencies and other USBR personnel to ensure the best solution to a given situation is implemented.

10. During the course of my long tenure with USBR, I have experienced several changes in its operations due to legislation enacted by Congress. This is particularly true where environmental issues are concerned.

11. For example, on October 27, 1986, Congress passed the Coordinated Operations Agreement ("COA"), PL 99-546, which defines the rights and obligations of the CVP and the State Wat Project ("SWP") regarding Sacramento Basin and Delta water

quality needs. With daily coordination, USBR and the State Department of Water Resources determine the target Sacramento-San Joaquin Delta outflow for water quality, for reservoir releases to meet in-basin needs, and for schedules to use each project's facilities for pumping and conveyance. The high degree of coordination necessary to meet these needs requires the exercise of discretion.

12. More recent environmental initiatives and legislation include the December 15, 1994, Principles for Agreement on Bay-Delta Standards and the Central Valley Project Improvement Act ("CVPIA"). The Bay-Delta Accord (copy attached hereto as Exhibit "B") provided a mechanism for additional protection for the Bay Delta estuary by encompassing the alternative Delta operations for the CVP and the SWP consistent with several Biological Opinions issued under the Endangered Species Act and agreement on new water quality and flow standards within the Delta. The Bay-Delta Accord also provided for coordination with the CVPIA (copy attached hereto as Exhibit "C"). In 1995 the State Water Resources Control Board ("SWRCB") issued Order WR 95-6 which modified the water rights authorizing the diversion and use of water from the Delta by the CVP and SWP to be consistent with the Bay Delta Accord. Therefore, the long-term operations planning and daily operations decisions must take into account the intent and requirements not only of the Bay-Delta Accord, but also WR 95-6, the two Biological Opinions, and CVPIA. Interpretation and implementation of these various laws and other legal requirements, and operational decisions must be integrated with the authorized purposes of the project. The result is a careful

balance in managing the water resource on an integrated, system-wide basis in a manner that meets the obligations of the CVP. This balance is achieved and maintained only through cautious and prudent management of the system.

13. In addition, other operational changes have been affected as a result of the SWRCB's 1995 Water Quality Control Plan (copy attached hereto as Exhibit "D"). The purpose of the Plan is to establish water quality control measures which contribute to the protection of beneficial uses in the Bay-Delta Estuary. The Plan provides the component of a comprehensive management package for the protection of the Estuary's beneficial uses that involve controls on salinity (from salt water intrusion and agricultural drainage) and water project operations (flows and diversions). This Plan is implemented in conjunction with state water plans and policies, and with programs and laws such as the CVPIA. Coordination and implementation of new legislation such as this Plan or the CVPIA with existing statutes, contracts and directives requires careful, discretionary consideration.

14. Significant impacts on CVP operations have occurred in connection with USBR's implementation of requirements of Biological Opinions issued under the federal Endangered Species Act. The Biological Opinion covering the CVP's and the SWP's operational impacts on the winter-run chinook salmon provides for alternative operations of the two projects to protect the endangered species. Similarly, the Biological Opinion covering the CVP's and the SWP's operational impacts on the endangered Delta smelt provides alternative operations within the Delta for the protection of the species. The alternative operations

include such measures as providing positioning of the salt/fresh water interface as the habitat for the smelt, as well as placing limitations on export operations.

15. On May 29, 1997, USBR dedicated the newly constructed $80 million Temperature Control Device ("TCD") at Shasta Dam. The TCD allows for the selective withdrawal of water from different levels of Shasta Lake in order to improve the habitat for certain species of fish. In addition, the CVPIA authorized the dedication of 800,000 acre-feet of yield annually to improve the fisheries. This water is to be utilized by and distributed across the entire CVP. USBR issued final guidelines on allocation of the 800,000 acre-feet of water on May 28, 1996 (copy attached hereto as Exhibit "E"). USBR also issued a draft administration proposal on management of the 800,000 acre-feet of water on July 1, 1996 (copy is attached hereto as Exhibit "F").

16. USBR has consistently coordinated with, and been receptive to recommendations received from various federal and state agencies concerning CVP operations, especially those recommendations addressing enhancement and protection of the environment. An example of this coordination is the January 1980 "Memorandum of Understanding Among State Water Resources Control Board, United States Water and Power Resources Service [USBR], and Department of Fish and Game to Implement Actions to Protect the Sacramento River System from Heavy Metal Pollution from Spring Creek and Adjacent Watersheds" ("the 1980 MOU") (copy attached hereto as Exhibit "G"). For the past 17 years, USBR has attempted to operate its northern CVP facilities to meet the objectives of the 1980 MOU, and in doing so, minimize the impacts

of Spring Creek's acidic, metals-laden waters on the Sacramento River ecosystem. Examples of earlier efforts to operate CVP facilities to off-set the effects of Spring Creek waters include recommendations from DFG for operating the new Spring Creek Debris Dam (copy attached hereto as Exhibit "H"), and a letter from USBR to DFG dated September 10, 1969, setting forth criteria agreed to by USBR for the operation of Spring Creek Debris Dam (copy attached hereto as Exhibit "I"). Operations of the CVP are also governed by existing water rights and water contracts, which impose legal obligations on the water contained in the reservoirs of the CVP. Discretionary decisions are required to coordinate implementation of operational recommendations received from various state and federal agencies within the legal obligations imposed on the CVP.

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I declare under penalty of perjury that the foregoing is true and correct.

Executed in Sacramento, California, on the 30th day of May, 1997.

Lowell Ploss

Lowell Ploss

USBR Letter re Operation Efficiency of SCDD

Following is a letter dated September 25, 1997, signed by Robert D. Shaffer for Frank Michny, Acting Regional Environmental Officer, of the U.S. Bureau of Reclamation (USBR), Mid-Pacific Region, to Rick Sugarek, U.S. Environmental Protection Agency, Region IX.

The letter returns to Mr. Sugarek responses to questions contained in the attachment, a letter from Mr. Sugarek to Ms. Kerry Rae, USBR, dated July 14, 1997. The attachment was prepared in response to comments submitted by Rhone-Poulenc regarding the operating efficiency of the SCDD.

United States Department of the Interior

BUREAU OF RECLAMATION
Mid-Pacific Regional Office
2800 Cottage Way
Sacramento, California 95825-1898

IN REPLY
REFER TO:

MP-150
ENV 5.00

SEP 25 1997

Mr. Rick Sugarek
Environmental Protection Agency, Region IX
H-6-2
75 Hawthorne Street
San Francisco, California 94105

Subject: Analysis of Spring Creek Debris Dam Operational Efficiency
(Your Memorandum dated July 14, 1997)

Dear Mr. Sugarek:

Reclamation is pleased to provide the enclosed responses to questions related to analysis of factors that may impact the operational efficiency of Spring Creek Debris Dam (SCDD). We regret the inability to respond to the entire operational hypothetical within the time frame required by the Environmental Protection Agency (EPA). Should the opportunity exist, Reclamation will respond to the remaining operational questions. We hope that the responses we have provided enable you to better understand Reclamation's capabilities and limitations regarding SCDD operations. We appreciate that you requested our input and did not make assumptions regarding Reclamation's operational capabilities in your determination of remedial strategies at the Iron Mountain Mine (IMM) Superfund Site.

We understand that the EPA is evaluating different remedial strategies in the continuing effort to clean-up the IMM Site. This evaluation includes assessing a range of possible remedial controls and water management strategies. We understand that in posing the enclosed questions, EPA is not looking for any commitments from Reclamation, but rather is only seeking input based on Reclamation's operational experience that will enable you to make an informed remedy selection. To this extent, Reclamation is interested in providing EPA with a better understanding of the complexities involved in operating the SCDD and other aspects of the Central Valley Project (CVP) with the presence of acid mine drainage (AMD) emanating from the IMM Site. However, in assessing remedial options for this Site, EPA must bear in mind that Reclamation has no responsibility for off-setting the impacts of AMD from the IMM Site, or requirement to operate the CVP, including the SCDD, to insure attainment of water quality standards. This responsibility lies with the past and present owners and operators of the IMM. Reclamation hopes that the information provided in this response will assist EPA in making the determination that the final remedy selected for the IMM Site should be focused on source control measures and not rely on CVP operations.

With regard to the hypothetical operating conditions contained in EPA's series of questions, Reclamation would make the following general observations. The SCDD is presently operated in accordance with the objectives set forth in the cooperative 1980 "Memorandum of Understanding Among State Water Resources Control Board, United States Water and Power Resources Service (Reclamation), and Department of Fish and Game" (1980 MOU), not in accordance with the State

Basin Plan Standards (SBPS). The SBPS are considered during critical situations, but Reclamation's main objective during potential spill situations is to coordinate with the Department of Fish and Game to minimize impacts to the Sacramento River fishery and to the CVP.

Although EPA references attainment of SBPS as a remedial goal, you have also identified many variables which could greatly impact the ability to attain these standards through a water management scenario. Because of the many uncertainties inherent in a water management approach to controlling IMM AMD flows, Reclamation strongly encourages EPA to require treatment of the IMM AMD before it is permitted to flow downstream to the SCDD.

Reclamation has responded to the questions you posed as if we were evaluating the value and feasibility of including each variable as part of an operational strategy to achieve a high degree of operational efficiency at SCDD, such as that represented in the May 1996 Water Management Feasibility Study Addendum (1996 FSA). The 1996 FSA utilized an operational efficiency at SCDD of 75% to analyze certain remedial alternatives. The conclusion Reclamation has come to in evaluating such a hypothetical operational system is that a highly efficient operational strategy such as that represented in the 1996 FSA is not practicable. The large number of variables and the large quantity of high quality data which would have to be collected under difficult conditions on an extremely rapid turnaround time accounts for only part of the virtual impossibility of such an operational strategy.

If you require additional information regarding this matter, please contact Kerry Rae at (916) 978-5037.

Sincerely,

ACTING Robert D Shaffer

For:

Frank Michny
Acting Regional Environmental Officer

Enclosure

cc: Regional Solicitor's Office, Pacific Southwest Division
(Temi Berger)
CVO-400 (Bowling, Fujitani)
NC-200 (Gibbons, Sarsfield)
(each w/enclosure)

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION IX
75 Hawthorne Street
San Francisco, CA 94105

July 14, 1997

MEMORANDUM

TO: Kerry Rae, Superfund Liaison
U.S. Bureau of Reclamation

FROM: Rick Sugarek, Remedial Project Manager
U.S. Environmental Protection Agency

SUBJECT: Analysis of SCDD Operation Efficiency for Use in the Iron Mountain Mine Water Quality Model (IMM WQM)

This memorandum provides a series of questions related to EPA's analysis of factors that could impact the efficiency of practicable Spring Creek Debris Dam (SCDD) release operations to assure dilution of Iron Mountain Mine (IMM) heavy metal discharges to safe levels with Sacramento River flows. Over the past several years, EPA and USBR personnel have discussed these issues extensively in past meetings and telephone conferences.

As we have discussed, EPA would appreciate USBR written responses on the issues outlined in the attached SCDD operations workbook. The attached workbook is intended to facilitate your efforts to provide detailed information.

USBR input regarding the practicability of acquiring required SCDD operational data and taking data uncertainty into consideration during operational decision making (along with other factors) is important for consideration in designing an operational strategy to assure the attainment of protective State Basin Plan Standards (SBPS) as a component of EPA's interim and final IMM remedies. Thank you in advance for your attention to this matter.

SCDD OPERATIONS CONCEPT

Efficient operation of the SCDD outlet works to manage the safe release of IMM contaminated Spring Creek waters to Keswick Reservoir requires:

- field sampling to acquire extensive water quality and surface water flow data to adequately characterize all surface water inflows to the Keswick Reservoir;
- analysis of water samples for key water quality parameters for determining the appropriate SCDD release rate, including the dissolved copper and zinc concentrations, hardness, and chemical parameters related to metal precipitation;
- the performance of the Keswick Reservoir mass balance (including an estimate of the extent to which metals may precipitate from the dissolved form to particulate form) to determine the allowable SCDD release that would assure attainment of the protective SBPS in the Sacramento River;
- decision making regarding the need for adjustment to SCDD operational controls in coordination with all interrelated CVP operations; and
- making changes to the operational settings of the SCDD outlet works gates and intake louvers to implement the appropriate controls, and verifying that the changes have been correctly implemented.

Effective and timely implementation of each of these elements is critical to the success of SCDD release operations. Issues related to each of these efforts are identified in the following sections.

General Comments

In the following responses to queries in this workbook, it should be recognized that where Reclamation identifies an activity as potentially feasible based on adding staff or resources, we are only identifying physical performance of that activity as potentially practicable; we are not stating that the activity is administratively feasible. In fact, obtaining additional staffing resources could be difficult as Reclamation has been significantly downsized in recent years.

Additionally, while Reclamation has provided substantive and technical responses to the scenarios posed, it must be noted as a general matter and as applicable to all responses provided herein that Reclamation disagrees with certain statements contained in the questions posed by EPA which in any manner suggest or *hypothesize that Reclamation has any responsibility for attainment of State Basin Plan Standards (SBPS) through its operation of SCDD or the CVP, or for managing IMM contaminants.*

For the purpose of this evaluation, Reclamation has interpreted the terms "timely" and "real time" to represent frequencies or periods of one to four hours.

ISSUES

I. Field Sampling Program

Field sampling to support SCDD release operations requires the performance of field sampling over a wide area, under adverse storm conditions while adhering to rigorous protocols to assure the representativeness of water quality samples with dilute metal concentrations taken from surface waters during intense storms and often under dangerous flood conditions. Support for SCDD operations also requires accurate measurement, or estimate, of CVP facility releases and Keswick Reservoir storm inflows.

I.A Historic data indicate that water quality measurements in the Sacramento River below Keswick Dam (pH, hardness and copper and zinc concentrations) vary widely over short periods of time during storm events.

1) Do you agree that an intensive field sampling program would be required to assure the accurate characterization of these fluctuations?

Yes, to accurately characterize fluctuations in the water quality below Keswick Dam, a very intensive field sampling program would be required. Significant fluctuations in water quality may occur frequently throughout storm events.

2) Do you agree that this variability in conditions in the Sacramento River during storms is an important consideration for real time operational decision making to assure highly efficient SCDD operations?

Yes, the variability in Sacramento River conditions during storms is a very important consideration in maximizing "operational efficiency" at SCDD. The variability narrows the window Reclamation must target when making operational decisions. However, a program which would be intensive enough to accurately characterize fluctuating water quality below Keswick during highly variable storm events would require significantly greater resources than Reclamation currently has available.

3) Do you agree that this variability in conditions in the Sacramento River during storms significantly limits the ability of SCDD operations to efficiently manage the releases of IMM contaminants while assuring attainment of the SBPS?

Reclamation strongly agrees that the variability in Sacramento River conditions during storms significantly limits the ability of SCDD operations to assure attainment of the SBPS.

I.B Water quality samples taken at the current Sacramento River sampling point below Keswick Dam may not be representative of conditions in the Sacramento River, particularly during periods of high side flow due to accretion during storm runoff events.

1) Do you agree that acquiring representative samples at this sample point is central to the task of assuring highly efficient SCDD release operations to maximize SCDD releases while assuring compliance with the protective SBPS?

Acquiring representative data below Keswick Dam would be one of several keys to maximizing SCDD releases if trying to attain the SBPS through operations guided by a mass balance or other complex operational equation. Current operations based on the targets and equations provided in the 1980 MOU are not impacted by the accuracy of measurements below Keswick Dam because the measurement is not utilized in the current operational equation. However, acquiring representative samples provides a more accurate measurement of the degree to which current operations are successful in protecting the Sacramento River fishery, and also provides a more accurate determination of "operational efficiency" as defined by EPA. Operations guided by a complex operational model would undoubtedly be sensitive to accurate and representative measurements below Keswick and at other locations where flows contribute to the overall mass balance of volume and concentration below Keswick.

2) Do you agree with EPA's analysis that dilute side-flows at this location may result in an improper measurement of the true copper concentration in the Sacramento River, and could result in noncompliance (a higher true copper concentration in the portions of the river that were not diluted by the side flow)?

Mixing patterns directly above and below Keswick Dam are unknown, so it is possible that side flows could be more dilute as a result of bank run-off. However, it is the opinion of Reclamation's sampling personnel that the historical point of sample collection below Keswick Dam does not receive a large volume of run-off from the bank. On past occasions, Reclamation has initiated discussions with interested agencies regarding the use of equal-width depth-integrated sampling below Keswick, which is normal protocol for sample collection by Regional office staff. However, because of the lack of a cable way or footbridge at the historical point of sample collection, other agencies expressed hesitation to move downstream away from that point to a location where a footbridge is available. The footbridge that is available downstream from Keswick Dam is downstream of a significant source of runoff during *precipitation events which could dilute copper concentrations.*

3) Do you agree with EPA estimates that an error of as little as 1 ppb in the measurement of the dissolved copper concentration at the Keswick Dam sampling point, considering the hardness of Sacramento River waters measured during the January 1995 storm, would result in an error in the Keswick Reservoir mass balance of approximately 18 percent (assuming SBPS = 5.6 @ hardness of 40 ppm) to 27 percent(assuming SBPS = 3.7 @ hardness of 25 ppm)?

Reclamation agrees that an error of as little 1 ppb copper would result in the stated error in the Keswick Reservoir mass balance. However, as stated above, it is unknown whether the impact from side flows on samples collected at the current bank location below Keswick Dam might be as high as ±1 ppb dissolved copper.

4) Do you agree that a further study should be planned and performed to define the extent to which measurements at this sampling point may be impacted by sideflow, or conversely to identify an alternate sampling point?

As stated above, Reclamation attempted to initiate discussions on this matter with other interested agencies, but met with very little interest. Concern has been expressed regarding the safety of sampling crews trying to collect a sample during high flows from anywhere other than the bank as is standard practice. Consistency among agencies and with past data has also been expressed as a reason to maintain the current sampling location. A simple study of differences in sampling points below Keswick was conducted by the State several years ago, but Reclamation feels that the data obtained from that study was inconclusive. Reclamation does feel that a more definitive study would be useful in determining the extent to which sampling location impacts measurement of the true dissolved copper concentration below Keswick Dam.

5) Strong Sacramento River flows, during storms, often create dangerous conditions for sampling on the river below Keswick Dam. Do you agree that mid-stream sampling on the river during storms does not appear to be a practicable option to assure representative samples?

As indicated in the prior response, concern regarding the safety of sampling crews has been a primary reason why the point of compliance for the SBPS has remained on the bank of the Sacramento River below Keswick.

6) If it is not possible to identify a practicable sampling

point where the influence of side-flows cannot be eliminated, do you agree that it would be appropriate to allow for a margin of safety in SCDD operational targets to assure compliance with appropriate SBPS during periods of high side-flow?

If such a margin of safety were feasible, this might be an acceptable approach. However, meeting even the emergency objectives in the 1980 MOU can be extremely difficult under storm conditions. Reclamation's Central Valley Operations (CVO) staff currently uses professional judgement of conditions and forecasts to allow for a margin of safety in targeting the 1980 MOU objectives whenever and to the greatest extent that conditions afford that opportunity.

I.C **Keswick Reservoir accretion flows are characterized by an extreme peak nature related to storm runoff. These accretion flows enter Keswick Reservoir over a wide area, from Shasta Dam to Keswick Dam.**

1) Do you agree that it would be difficult or impracticable to fully characterize the Keswick Reservoir accretion flows for purposes of "real time" operations?

The distance that sampling crews would have to cover and the number of potentially significant accretions flows needed to "fully characterize" the accretion from Shasta to Keswick Dam would be large. More than one sampling crew would be required to collect "real time" data over such a large area, and the resources required to cover that distance and to analyze such a large number of samples makes full characterization of the Keswick Reservoir accretion flows impracticable.

2) Do you agree that it would be appropriate to focus regular/routine field sampling efforts on characterization of the three major sideflows (Cottonwood Creek, Motion Creek and an unnamed side-stream) that comprise approximately 90 percent of the accretion flow?

Reclamation is not familiar with the relative contributions that certain sideflows make to the Sacramento River between Shasta and Keswick Dams. However, focusing sampling efforts on a few major sideflows would certainly be appropriate, especially if they constitute approximately 90% of the major accretions.

3) Historic data indicate that the water quality of accretion flows (pH, hardness and copper and zinc concentrations) varies widely over short periods of time during storm events. Do you agree that an intensive field sampling program is required to fully characterize these fluctuations

for consideration in operational decision making?

Characterization of these flows would likely be necessary components of a mass balance operational model. This would require resources well beyond Reclamation's current resource capabilities. Sampling would have to be performed from a boat and would be dangerous under storm conditions, and the time required for sampling would likely be inhibitive to real time operations even with multiple crews. It would not be likely that samples from several accretion flows could be obtained in less than an hour, even with two boats and crews. A more feasible approach might be to obtain a sample from Keswick Reservoir just upstream of the confluence of Spring Creek, but this would also require sampling from a boat and would still be dangerous to staff.

4) Do you agree that it is difficult to acquire representative samples from the major accretion flows during storms due to the peak nature of the inflows to Keswick Reservoir, their variability during storms, and the difficulty associated with performance of sampling under storm/flood conditions?

Yes.

5) Do you agree that estimation of the flow rates of the accretion flows, by calculation based upon CVP reported Spring Creek Reservoir inflows, would introduce some level of uncertainty into the performance of the Keswick Reservoir mass balance?

Yes.

6) Do you agree that it would be practicable to perform a study to obtain field measurement of the major accretion flows and/or field observations to reduce this uncertainty?

No. A study to obtain field measurement of the major accretion flows into Keswick Reservoir would provide data for that one precipitation event, but would not provide data which would reliably reduce the uncertainty of estimated flow rates during subsequent events. Precipitation rates will always vary over the watershed, and while average flow relationships might be developed, the uncertainty may not be any smaller than the uncertainty of calculated accretion flow rates based upon Spring Creek inflows.

7) Do you agree that it would <u>not</u> be practicable to obtain field measurements of the major accretion flows and/or field observations on a routine basis throughout storm events for use in operational decision making?

Reclamation agrees it would be nearly impossible to obtain *either frequent samples or flow measurements from the major accretion flows on a routine basis during storm events. To attempt to collect such data would be extremely resource intensive and dangerous to staff.*

I.D Historic data indicate that metal precipitation rates in Keswick Reservoir (copper and zinc) vary widely over short periods of time during storm events.

1) Do you agree that accurate measurement of the metal concentrations in Keswick Reservoir and the Spring Creek arm of Keswick Reservoir (SCAKR) to define the real time metal precipitation rates during storm events would provide important information relevant to assuring highly efficient SCDD release operations and compliance with the protective SBPS?

   If operations were defined by a mass balance model, which would likely be necessary to meet a 75% "operational efficiency" at SCDD, information regarding real time precipitation rates in Keswick Reservoir and the SCAKR would be necessary. Accurate measurement of metal concentrations would be needed to define these precipitation rates.

2) Do you agree that the observed significant degree of variability in the metal precipitation conditions in the Sacramento River during storms significantly limits the ability of SCDD operations to efficiently manage the releases of IMM contaminants while assuring attainment of the SBPS?

   Reclamation is unfamiliar with the degree to which precipitation rates may vary during storms, and does not know to what degree variations in metal precipitation rates may affect efficiency of SCDD operations, but agrees that this uncertainty certainly would impact attempts to assure attainment of the SBPS.

3) Do you agree that an intensive field sampling program would be required to fully characterize these fluctuations in metal precipitation rates for consideration in operational decision making?

   Yes.

4) Do you agree that performance of reservoir studies in SCAKR to acquire data regarding metal precipitation would be difficult under storm conditions that are critical to the successful operation of the SCDD?

   Yes.

5) Do you agree, even though metal precipitation rates are expected to vary significantly over short periods of time during storm events, that only limited SCAKR sampling could be expected to be physically possible?

Yes, sample collection would be very difficult under storm conditions, yet the collection of representative samples would be necessary over frequent intervals to provide useful real time data regarding the variability of precipitation rates.

6) Do you agree that the observed significant degree of variability in the metal precipitation conditions in the Sacramento River over the course of a wet season, and from year to year hinders the development of an engineering model or other approach that could be relied upon to estimate metal precipitation instead of "real time" measurements?

Although unfamiliar with the degree of variability in metal precipitation rates, Reclamation does recognize that precipitation rates are influenced by a number of variable factors. Accurate prediction or estimation of the conditions and many variable factors which affect precipitation rates does not seem possible.

7) If it is not possible to identify a practicable sampling program or model to fully characterize the variability in metal precipitation conditions in the Sacramento River during storms, do you agree that it would be appropriate to allow for a margin of safety in SCDD operational targets to assure compliance with appropriate SBPS?

If such a margin of safety were feasible, this might be an acceptable approach. However, meeting even the emergency objectives in the 1980 MOU can be extremely difficult under storm or other variable conditions. Reclamation's CVO staff currently uses professional judgement of conditions and forecasts to allow for a margin of safety in targeting the 1980 MOU objectives whenever and to the greatest extent that conditions afford that opportunity.

I.E Historic data indicate that the metal concentrations (copper and zinc) in the Spring Creek Reservoir inflow, and metal stratification effects in the reservoir, vary widely over short periods of time during storm events.

1) Do you agree that accurate measurement of metal concentrations in the inflow to Spring Creek Reservoir and metal stratification effects in the reservoir, particularly during storm events, would be important information for assuring effective SCDD release operations and compliance with the protective SBPS?

It would be helpful to know what metal concentrations may be entering Spring Creek Reservoir so that CVO staff can prepare for changing reservoir conditions and try to forecast the elevations at which the intake structure should be opened. Stratification data would provide information about which intake elevation would provide the most efficient management of the AMD in Spring Creek on a real time basis, but because of the sampling and analytical delay times involved, it is very possible that during periods of heavy inflows conditions in the Spring Creek Reservoir would change much too rapidly for collection of real time stratification data to be useful.

2) Do you agree that this significant degree in the variability in Spring Creek Reservoir conditions observed during storms significantly limits the ability of SCDD operations to efficiently manage the releases of IMM contaminants while assuring attainment of the SBPS?

Yes, the variability in reservoir conditions is one of several significant parameters which impact and severely limit the efficiency of SCDD operations to meet the target objectives of the 1980 MOU, and which would also limit attainment of the SBPS.

3) Do you agree that an intensive field sampling program would be required to fully characterize these fluctuations in Spring Creek Reservoir conditions for consideration in operational decision making?

Yes, during periods of high inflows, frequent and thorough sampling and analysis would be required to fully characterize the rapidly changing reservoir conditions if the data were to be useful to an operational model. This would be extremely resource intensive, and would be dangerous under storm conditions. Sampling in the reservoir can be hazardous under any conditions due to the levels of AMD emanating from IMM, but Reclamation's monitoring staff have indicated that sampling the inflows and body of the Spring Creek Reservoir under storm conditions would be extremely difficult and hazardous due to the water quality and limited access. These considerations would also make characterization of the fluctuating conditions very time-consuming.

4) Do you agree that performance of reservoir studies in SCR to acquire data regarding metal stratification is important for efficient SCDD operation, but is expected to be difficult under storm conditions that are critical to the successful operation of the SCDD?

As stated above, the information would be necessary for *highly efficient SCDD operations, but is not feasible due to the resource-intensive and dangerous nature of the sampling program that would be required. Sampling crews would be required to access the reservoir by boat for such a monitoring program, but it would be very difficult to access the reservoir with a boat under rapidly changing, high inflows, and would be very dangerous for crews to be on the reservoir in a boat under potential spill conditions. Reclamation would not put its staff in such a dangerous position.*

5) Do you agree, even though metal concentrations are expected to vary significantly with depth and over short periods of time during storm events, that only limited reservoir sampling could be expected to be physically possible?

Yes, the metal concentrations are expected to vary so much over short periods of time that collection of useful, real time data under storm conditions would not be practicable. Because of the hazards to staff, it is highly unlikely that Reclamation would initiate such a program even if collection of real time data were possible.

6) If it is not possible to identify a practicable sampling program to fully characterize the variability in Spring Creek Reservoir conditions during storms, do you agree that it would be appropriate to allow for a margin of safety in SCDD operational targets to assure compliance with appropriate SBPS?

If such a margin of safety were feasible, this might be an acceptable approach. However, meeting even the emergency objectives in the 1980 MOU can be extremely difficult under storm or other variable conditions. Reclamation's CVO staff currently uses professional judgement of conditions and forecasts to allow for a margin of safety in targeting the 1980 MOU objectives whenever and to the greatest extent that conditions afford that opportunity.

I.F CVP operational reporting could be relied upon to define flow rates for releases from CVP facilities for performing the Keswick Reservoir mass balance.

1) Do you agree that the CVP operational information could provide reasonably accurate engineering information for purposes of performing the Keswick Reservoir mass balance?

Very accurate information on reservoir elevations is available for Shasta, Keswick, and Spring Creek Reservoirs. Level indicators within the dams are accurate to within 0.01 feet and are calibrated periodically. From this information, reasonably accurate operational information *regarding reservoir and powerplant releases from Shasta, Keswick, SCPP, and SCDD is available. Flow measurements for releases are based on rating curves and are considered to be very reliable at approximately ±5% accuracy. Highly accurate sonic flow meters have been installed in a couple of the turbines at Shasta and Keswick, will eventually be installed in all of the CVP powerplants.*

2) Do you agree that additional QA/QC procedures would be necessary to assure the accuracy and reliability of this operational report as engineering information?

Raw data is telemetered on a bihourly basis to the California Data Exchange Center, and does not receive any screening. However, daily operational data, which is entered on Reclamation's operating reports, is screened for potential errors and is considered to be reliable. QA checks could be initiated on bihourly operational data; however, this would require additional staff or resources to accomplish.

I.G **Field sampling logistics are expected to be difficult for a number of reasons including the required sampling frequency and the wide-spread area over which samples must be taken.**

1) Do you agree that it would be necessary to rely on multiple sampling crews on each shift because of the wide-spread area over which samples must be taken?

Multiple sampling crews would definitely be necessary to sample the many locations previously discussed -- below Shasta Dam, several accretion flows into Keswick Reservoir, below Keswick Dam, up the SCAKR to the SCDD outlet, and in and above the Spring Creek Reservoir. Crews of at least two staff would be necessary for safety reasons, especially when sampling under storm conditions. Multiple boats would also be required. To sample each of these sites at a frequency which would fully characterize rapidly fluctuating conditions, sampling could be necessary as often as each hour and would be required around the clock. Night sampling poses not only additional safety risks, but could mean as many as three shifts of multiple sampling crews would be necessary. Such a monitoring program would be extremely resource-intensive and would expose staff to potentially dangerous conditions.

2) Do you agree that sample couriers would be needed to assure that samples are delivered to the laboratory expeditiously for analysis on a rapid turn-around time basis?

The more expeditiously samples are delivered to the *laboratory, the more rapidly data could be generated, and the greater its value would be to real time operational decision-making. If one were to go to the expense and level of effort previously described in such a monitoring program, it would not make sense to lose time in getting the samples to the laboratory for a rapid turn-around time analysis. However, the use of couriers only adds to the resources required for such an intense sampling program, making it that much more impracticable.*

II. Analytical Program

The water quality analysis program to support SCDD release operations requires the performance of analytical testing on multiple samples for multiple chemical parameters on a rapid turn-around basis while adhering to rigorous protocols to assure the accuracy and precision of testing results for samples with extremely dilute metal levels.

II.A Analyses for metal concentrations in the clean surface water releases from CVP facilities require rigorous analytical protocols with extensive QA/QC programs.

1) Do you agree that Analyses for metal concentrations in the clean surface water releases from CVP facilities, particularly those from Shasta Dam and the SCPH, require protocols that have detection limits of 0.5 ppb copper?

Because the SBPS for copper is quite low (5.6 ppb at a hardness of 40, and even lower at lower hardness), and concentrations of metals, especially dissolved metals, in flows from Shasta Dam and Powerplant and from SCPP are extremely low, a detection level of 0.5 ppb copper would be necessary to provide data that would be useful to a sensitive mass balance operational model. The range of precision and accuracy inherent in data with a higher detection limit would affect the accuracy with which the SCDD releases were calculated in such an operational system. It would not make sense to attempt to fully characterize the variability in parameters through an intense monitoring program without also reducing the variability in precision and accuracy of the analytical data as much as possible.

2) Do you agree that these analytical protocols require a high level of QA/QC?

Yes, a high level of QA/QC would be required to achieve detection limits of 0.5 ppb copper and to assure that no contamination of samples occurred during collection or during preparation for analysis.

3) Do you agree that these analytical protocols require longer analytical turn-around time than other less rigorous analytical methods?

Yes. Metals samples are currently analyzed at the Keswick Laboratory by graphite furnace (GFAA) or flame atomic-absorption (AA). Analysis by GFAA, which is necessary to achieve the low detection limit required for copper, is an inherently slow technique, and the analysis of 9 samples for copper would take approximately one hour, assuming that the analyst had the instrument calibrated and ready when the samples arrived. Calibration of the instrument requires a minimum of approximately 20 minutes for one metal if the process goes smoothly. The instrument must then be converted for the AA analyses of zinc and hardness parameters, which also takes time.

It is likely that samples from at least nine locations could be collected to support operations based on a mass balance operational model. However, due to the analytical times required, analysis of these samples for copper and then for any other parameters using the same process would essentially negate the usefulness of such a program for "real time" operational efficiency. Also, analyses for any metal type other than dissolved will take additional time for preparation before analysis can even begin. By definition, preparation for acid-soluble metals analysis requires at least 16 hours. Without the purchase of a microwave digestion system, total recoverable metals would require a minimum of approximately 4 hours, and the Keswick Laboratory does not currently have the capability to digest samples for total recoverable metals.

II.B Analyses for metal concentrations in accretion flows to Keswick Reservoir require rigorous analytical protocols with extensive QA/QC programs.

1) Do you agree that analyses for metal concentrations in the Keswick Reservoir accretion flows (which can vary from very low levels of metal, 1 ppb copper or less, to levels approaching the SBPS of 5.6 ppb copper (at 40 ppm hardness), also require protocols that have detection limits of 0.5 ppb copper?

Yes, for the same reasons stated in II.A.1.

2) Do you agree that these analytical protocols require a high level of QA/QC?

Yes, for the same reasons stated in II.A.2.

3) Do you agree that these analytical protocols require longer

analytical turn-around time than other less rigorous analytical methods?

Yes, for the same reasons stated in II.A.3.

II.C Analyses for metal concentrations in Keswick Dam releases require rigorous analytical protocols with extensive QA/QC programs.

1) Do you agree that analyses for metal concentrations in the Keswick Dam releases (which can vary from very low levels of metal, 2 ppb copper or less, to levels approaching the SBPS of 5.6 ppb copper (at 40 ppm hardness), also require protocols that have detection limits of 0.5 ppb copper?

For the same reasons stated in II.A.1, a detection limit of 0.5 ppb copper would be preferable for analysis of copper concentrations below Keswick Dam.

2) Do you agree that these analytical protocols require a high level of QA/QC?

Yes, for the same reasons stated in II.A.2.

3) Do you agree that these analytical protocols require longer analytical turn-around time than other less rigorous analytical methods?

Yes, for the same reasons stated in II.A.3.

II.D The capability of current analytical techniques must be considered in making operational decisions.

1) Do you agree that the accuracy of analytical techniques for measuring surface water samples with very low metal levels may itself be a significant uncertainty in assuring efficient SCDD release operations to comply with the SBPS. For example an analytical error of 1.0 ppb copper in the measurement of Keswick Dam releases is itself 17.8 percent of the SBPS for copper (5.6; hardness = 40 ppm).

Reclamation agrees that smaller analytical uncertainty represents a smaller proportion of the SBPS and therefore reduces a potentially significant source of uncertainty if one were attempting to meet the SBPS.

2) Do you agree that the analysis of Keswick Reservoir inflows and releases for hardness (25 to 50 ppm), alkalinity (25 to 60 ppm), TDS (approximately 75 ppm), pH (6.0 to 7.5), iron (approximately 220 ppm) and aluminum (approximately 150 ppm) content are well within laboratory analytical capability and should be routine?

While these are common analyses, most are not needed in order to meet the target objectives of the 1980 MOU. Hardness and pH are monitored below Keswick Dam along with zinc and copper, but the Keswick Laboratory does not currently have the capability to analyze iron, aluminum, or TDS. Aluminum can be problematic to analyze by FAA. In order to achieve a much higher operational efficiency at SCDD, Reclamation agrees it is likely that such parameters would be necessary components of a mass balance operational model, but adding these parameters to the intense monitoring programs discussed previously would add additional sampling and analytical time to an already overburdened program. The addition of these parameters to the Keswick Laboratory's capabilities would require the purchase of additional equipment, additional analytical staff to meet rapid turnaround times, additional space for equipment and staff, and would not be practicable.

II.E The turn-around time for laboratory analyses must be considered in making operational decisions.

1) Organic carbon, total suspended solids (TSS) or total dissolved solids (TDS) content may impact SCDD release operations, particularly related to accretion flows during storm periods. Because of the peak nature of the accretion flows, do you agree that turn-around time would be critical in considering these factors in making SCDD operational decisions?

These are also common analyses, but they are not needed by Reclamation in order to target the objectives of the 1980 MOU. The intent of an operational model which is detailed enough to include these parameters would be to assess SCDD operational requirements based on frequent, accurate measurements of the many variable conditions in the system, so turn-around time would be critical in considering these factors. However, analyses such as TSS and TDS are time-consuming by definition of the methods, and would not provide useful data for a real time model. Reclamation's Keswick Laboratory does not currently have the capability to analyze TSS, TDS, or organic carbon (TOC), and it is believed that Reclamation's local contract laboratory sends TOC samples out of town for analysis. Even if the analyses could be performed in a timeframe that would provide useful data, the cost of contracting with a private laboratory for these analyses on a rapid turn-around time, at the frequency and number of sites that would provide useful information under variable storm conditions, would be prohibitive. The cost of adding the additional equipment and staff to the Keswick Laboratory would also be prohibitive. Analyses that can not be performed at the Keswick Laboratory would also be *limited to the operating hours of a contract laboratory, which would not provide data around the clock or on weekends.*

2) Stratification of metals in the Spring Creek Reservoir may, at least at times, be a significant parameter in the operation of the SCDD releases. Because of the peak nature of the Spring Creek Reservoir inflows, do you agree that turn-around time would be critical in considering Spring Creek Reservoir metal stratification in making SCDD operational decisions?

As stated above, the intent of an operational model which is detailed enough to include this parameter would be to assess SCDD operational requirements based on frequent, accurate measurements of the many variable conditions in the system, so turn-around time would be critical in considering reservoir stratification.

3) Precipitation of metals in the Spring Creek arm of Keswick Reservoir (SCAKR) is a significant parameter in the operation of the SCDD releases. Because of the expected variability of conditions related to the precipitation of metals in SCAKR, do you agree that turn-around time would be critical in considering metal precipitation in making SCDD operational decisions?

Turn-around time would be critical to the intent of utilizing a mass balance operational model to assess real time SCDD operational requirements. Precipitation of metals would be a key component of that mass balance model, so turn-around time would be critical to the usefulness of this parameter. However, data on several chemical parameters from several locations is required to assess precipitation rates, and it is not likely that a rapid turn-around time is feasible for the necessary chemical analyses which would be required. It is therefore highly unlikely that information on fluctuating precipitation rates would be available in the necessary turn-around time.

4) Monitoring compliance with SBPS in receiving waters is a significant parameter in the operation of the SCDD releases. Because of the expected variability of conditions related to the metal fluctuations under highly variable storm conditions, do you agree that turn-around time would be critical in making SCDD operational decisions?

Reclamation agrees that measurement of metal concentrations below Keswick Dam is essential to assess the efficiency and effectiveness of SCDD operations, whether operations are attempting to target the 1980 MOU objectives or the SBPS. If SCDD operations were driven by an operational model based *on collection of real time data, turn-around time for analysis of samples collected below Keswick Dam on the same real time basis would be critical for operational decision-making.*

III. The Keswick Reservoir Mass Balance Approach for the Calculation of Allowable SCDD Release Rates

In determining the maximum safe level of release of IMM heavy metal contaminated waters stored in Spring Creek Reservoir, a mass balance approach is employed to calculate the allowable SCDD discharge that would assure meeting the protective State Basin Plan Standards (SBPS) in the Sacramento River.

Keswick Reservoir and the CVP facilities that provide inflows and releases include releases from Shasta Dam, the Spring Creek Power House (SCPH), the Spring Creek Debris Dam (SCDD) outlet and Keswick Dam. Storm water runoff and other inflow ("accretion flow") that drain the area adjacent to Keswick Reservoir provide an additional flow component and metal load.

The mass balance calculational approach depends upon the accurate estimation of the contribution of numerous Keswick Reservoir inflows and the Keswick Dam releases both in terms of flow volume and metal concentrations. Under this approach the amounts of dissolved copper and zinc entering Keswick Reservoir (from sources other than the IMM heavy metal contaminated waters of the Spring Creek watershed that comprise the SCDD releases), and the amounts of dissolved copper and zinc that would be allowed to leave the reservoir while meeting the protective SBPS are estimated. By comparing these estimates, and taking into consideration the amount of copper and zinc that would be expected to precipitate out of solution as particulate matter in Keswick Reservoir, the allowable SCDD copper and zinc release can be calculated. The allowable volume of the SCDD outlet release is then determined based upon the characteristics of the waters stored in Spring Creek Reservoir.

III.A Shasta Dam Releases

1) Do you agree that accurate Shasta Dam release rate flow information is required to successfully manage a potential remedial action that would depend on these flows to safely dilute IMM AMD metal discharge loads?

   Because SCDD releases would be calculated based on the available flows in the Sacramento River, accurate knowledge of flow rates below Shasta Dam would be a necessary component of efficient SCDD operations. However, dilution is not an appropriate means of pollution control and these flows should not be relied upon for successful management of

IMM AMD.

2) Do you agree that bi-hourly CVP operations data indicate significant variability in the Shasta Dam release when the Shasta Dam power house is operated to produce peak power?

One purpose for the existence of Keswick Dam is to regulate Sacramento River flows so that the Shasta Powerplant can produce peak power as it was designed to. Shasta Powerplant releases can vary significantly during peaking operations as observed in bihourly operations data.

3) Shasta Dam release peak discharges are stored in Keswick Reservoir and released into the Sacramento River to regulate river flow. Do you agree that the storage and later release of these waters impacts the physical availability of waters in the lower third of Keswick Reservoir to assure dilution of the IMM contaminant inflows?

The operation of Keswick Dam to store and regulate flows from Shasta Dam and Powerplant may impact the availability of waters in lower Keswick Reservoir to dilute IMM contaminant inflows. This is a public reservoir and producing peak power is a Congressionally authorized purpose for Shasta Powerplant and for Keswick Reservoir.

Dilution of IMM AMD is not an authorized purpose for the CVP powerplants or reservoirs, and these waters should not be relied upon for such dilution.

4) Do you agree that CVP reported daily average Shasta Dam release flow rates could be considered as adequate input to the Keswick Reservoir mass balance during periods when Shasta Dam is predominantly operated for peak power production? To what extent do you believe that this approach would introduce uncertainty into the mass balance?

During periods of peaking operations, Shasta releases can and do vary considerably. Use of a daily average of this release could affect the calculation for a mass balance in Keswick Reservoir. The effect would depend upon mixing and travel time in Keswick Reservoir and time step for modeling. Reclamation cannot comment on the extent to which Shasta daily average release rates would affect the mass balance without further study.

5) Do you agree that CVP reported daily average Shasta Dam release flow rates could be considered as adequate input to the Keswick Reservoir mass balance during periods when Shasta Dam is predominantly operated for flood control releases or to produce base load power? To what extent do you believe that this approach would introduce uncertainty

into the mass balance?

During flood operations, Shasta operations for peaking may be significantly reduced. The powerplant may be at or near to plant capacity, but releases may also vary significantly during the day. Flow rates could vary to meet changing flood operation objectives and to compensate for variability in side flows between Shasta and Keswick Dams. Rates may vary based on reservoir flood storage and river levels downstream. The extent to which use of daily averages during flood operations would introduce uncertainty into a mass balance model will vary with specific storm events. Daily averages will mask these fluctuations through the day.

If Shasta powerplant is operated as a base load and release is held constant throughout the day, there would be little difference between daily average release and the bihourly values. The impact of using daily averages during these periods for a mass balance water quality model is likely to be much smaller.

6) The CVP operational summary is currently maintained for USBR record keeping and operational decision making requirements, but is not relied on by the USBR for the performance of a detailed Keswick Reservoir metals mass balance. Do you agree that future reliance on the CVP operational record for input into the Keswick Reservoir mass balance would require that quality control and quality assurance (QA/QC) procedures be augmented to assure the accuracy and precision of the operational record for use as engineering data?

Reclamation's daily operational summary data does receive some QA/QC review on flows and reservoir storage and elevations. Other uncertainty also exists: accretion flows are based on calculations and are therefore uncertain, uncertainty of approximately +5% exists for rating curves for outlet works, spillway flows have some uncertainty, and most generator release rates are currently calculated from power production rates. Increased QA/QC could require additional equipment for checks such as water level indicators, gate indicators, and flow meters. The bihourly data does not receive any review. If bihourly data was to be used for a mass balance operational model based on real time data, then QA/QC checks on that operations data would be needed, and would be required on a real time basis. However, the additional attention to data would require a significant increase in CVO staff time, which would be infeasible during storm operations, and would possibly require additional staff which is prohibitive.

7) Do you agree that although Shasta Lake is a large reservoir, the water quality in the Shasta Dam releases can vary due to

storm water inflows? For example, EPA data acquisition efforts indicate that the size of the reservoir reduces the observed variability in the quality of the Shasta Dam releases. Copper concentrations have been observed to vary from concentrations of less than 1 ppb to approximately 2 ppb of dissolved copper. An error of 1 ppb in the reported Shasta Dam release copper concentration, at a time when the Shasta Dam release is the dominant dilution flow, would result in an approximate 12 percent error in the calculation of the allowable SCDD release (assumes controlled release conditions; copper precipitation rate of 35 percent; SBPS = 5.6 @ 40 ppm hardness).

The large size of Shasta Lake and its watershed certainly factor into the relatively constant water quality observed below Shasta Dam. A variability of ±1 ppb in dissolved copper concentrations is very small, but may occur during storm events. At the stated conditions, the error (±0.65 ppb copper) may equate to 12 percent of the SBPS, but is barely larger than the variance expected from an analytical method with tight precision and accuracy and a low, 0.5 ppb detection limit. When the flows from Shasta Dam represent the dominant dilution flows, the significance of the variability to SCDD operational efficiency may only be as large as the uncertainty of the analytical method. However, SCDD operations based on a mass balance approach would require that variability in copper concentrations of flows below Shasta Dam be reflected as accurately as possible.

8) Do you believe that it may be necessary to monitor this station frequently because of its importance for assuring efficient SCDD operations?

To achieve highly efficient SCDD operations based on the mass balance of real time data, the concentration of metals in flows below Shasta Dam would be a required parameter. Data from this station should be acquired as frequently as any other parameter required for the model. As indicated previously, Reclamation would consider "real time" data to be collected every one to four hours.

9) Do you agree that acquiring hourly data to define conditions in the Sacramento River during storm events is technically feasible, but would be costly?

Acquiring hourly data from a station below Shasta Dam would only be technically feasible if multiple sampling crews and couriers were utilized. Also, multiple analysts with additional equipment and new space would be required around the clock at the Keswick Laboratory, because it is unlikely that a contract laboratory could be found which would accept samples throughout the night and on weekends. This is not a *realistic scenario, even if the enormous expense could be supported.*

10) Do you agree that analytical capability to accurately measure metal concentrations at the levels present in Shasta Dam releases requires a very high level of quality assurance.

As stated in III.A.7 and in II.A.2, Reclamation agrees that accurate measurement of the low concentrations of metals in flows from Shasta Dam requires very tight precision and accuracy and very low detection limits. This can only be achieved with a high level of quality assurance.

III.B Whiskeytown Lake/SCPH Release

1) Do you agree that accurate SCPH release rate flow information is required to successfully manage a potential remedial action that would depend on these flows to safely dilute IMM AMD metal discharge loads?

Reclamation strongly disagrees that any remedial action should depend on flows from SCPP for dilution. This is not an authorized use of CVP water and the volume or availability of these flows can not be guaranteed for the safe dilution of IMM AMD discharges.

Reasonably accurate flow rates from SCPP are a necessary component to efficient SCDD operations; however, because the flows can not be guaranteed, they should not be relied upon for successful management of IMM AMD.

2) Do you agree that bi-hourly CVP operations data indicate significant variability in the SCPH release because it is generally relied on to produce peak power?

One purpose for the existence of Keswick Dam is to regulate Sacramento River flows so that the SCPP can produce peak power as it was designed to. SCPP releases can vary significantly during peaking operations as observed in bihourly operations data.

Review of Evaluation of EPA's Metal Concentration and Load-Flow Regression Equations for January through March 1995

PREPARED FOR: Rick Sugarek/U.S. EPA

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Description of Document

The document, *Evaluation of EPA's Metal Concentration And Load-Flow Regression Equations for January through March 1995* (prepared for Stauffer Management Company [SMC] by Spaulding Environmental Associates [SEA], October 10, 1995 [SMC Vol. 32, Tab 2]) presents an evaluation of the copper concentration/load versus flow regression equations that CH2M HILL employed to evaluate the effectiveness of remedial actions proposed for Boulder Creek. The equations were included in the *Boulder Creek Remedial Alternative Study* (BCRAS) (U.S. EPA, 1995) and were presented to the Boulder Creek Peer Review Panel on August 10 and 11, 1995. The subject SEA review was conducted using data files that were provided to SMC on August 17, 1995.

Major Findings or Major Review Comments in Document

The SEA report provides an in-depth evaluation of the regression equations used in the *Boulder Creek Remedial Alternative Study* (U.S. EPA, 1995). The report listed the following major conclusions (Page 19, Section 4, Conclusions)

1. Comparison of the original SMC concentration data with that used by CH2M Hill (1995) shows that the data have been extensively "hand" edited without explanation or justification. In one case, serious timing errors have been introduced into the modified data set.

2. CH2M Hill has chosen to use predictions of the HSPF model rather than SMC data arguing that SMC's data contains inconsistencies between stations and significant uncertainties. These problems are never described nor is analysis provided that supports these statements. Documentation on the application, calibration, or verification of the HSPF model for January through March 1995 was not provided in time to perform a careful analysis to support this study. A cursory review shows that there is no quantitative analysis of the model's calibration, no verification of the model using an independent data set, and no systematic sensitivity of model predictions to input parameters. It is therefore impossible to accurately assess its usefulness for providing input data to the regression analysis. Comparison of the HSPF model predictions to observations shows that the model overpredicts the mean flows by as much as 10% and by as much as a factor of 2 during high-flow storm events for stations near the mouth of Boulder Creek.

3. Copper load versus flow is highly variable, but increases as one goes downstream, for stations upstream of BCW18 and is approximately constant downstream of this location. The primary source of metal loading is hence upstream of BCW18. The coefficients of determination of the regression equation are very low (0.2 to 0.4) upstream of BCW18 but higher (~0.9) downstream of this location.

4. CH2M Hill violates their own stated criteria and uses all data (without flow restriction) to generate load-regression equations for stations downstream of BCW18. Their regression equations hence overpredict the metals loads in the critical high-flow regime. Since the remedial alternatives mainly use load equations from these stations the result of their analyses are biased to higher loads.

5. CH2M Hill presents their regression equations in the form of copper load versus flow rather than the primary variables of copper concentration versus flow. This approach inflates the values of the coefficient of determination (by a factor of about 2) and gives the reader a false sense of the performance of the regression equation for the underlying data. In fact the concentration-based regression equation explains less than 30% of the variance of the data in Upper Boulder Creek (upstream of BCW18) and less than 50% in Lower Boulder Creek.

6. A series of sensitivity studies revealed the following:

   - Using a flow restriction on the data employed in the regression analysis substantially alters that regression equation coefficients and decreases the R^2.

   - The HSPF model overpredicts the flow compared to SMC observations, particularly at peak flows, and hence predicts higher copper loads at high flows than when SMC flows are used. The overpredictions can be as large as a factor of two at high flows (e.g., at BCMO) and significantly impact the evaluation of the alternative remediation scenarios.

7. At the criteria evaluation location, BCMO, the EPA flow-based regression equation overpredicts the copper loads, compared to the SMC flow- based regression equation, by about 20% at high flows (~300 cfs), and underpredicts the values at low flows (<55 cfs). The EPA regression equation does not include any flow restriction in the data used but instead uses all data and hence overpredicts the concentrations and loads at high flows independent of the flow data set. Overpredictions are typically 20%. The primary differences between EPA's and SMC's two final regression equations are the higher flows predicted by the HSPF model in the high-flow regime and the lack of a flow restriction in EPA's analysis. The combination of the two effects means that EPA's regression equation predicts 45% higher concentrations and loads than SMC's.

Summary of Conclusions

Given the fact that the calibration and validation of the HSPF model at high flows has not been demonstrated and that CH2M Hill's criticisms of the SMC flows are undocumented by reference or analysis, one must conclude that the CH2M Hill (EPA) regression equation substantially overpredicts the copper concentrations and loads in the important high flow regime at BCMO.

Response to Major Findings or Major Review Comments in Document

1. It is uncertain which "original SMC concentration data" SEA references. SMC had great difficulty submitting accurate and complete flow and water quality data to EPA during this period. For instance, the mouth of Boulder Creek (BCMO) January 1995 data were submitted by SMC to EPA on January 27, revised on February 4, and revised again by SMC on April 13, May 23, June 7, and June 18. SEA does not indicate in its review the continual problems SMC encountered during this period in providing data to EPA.

   The CH2M HILL Boulder Creek Peer Review Panel Report and the load regression equations were revised in the final report, dated September 19, 1995. This report was provided to the Peer Review Panel, SMC, and SEA. Backup electronic data files were provided to SMC and SEA on October 3, 1995. These files explicitly list the data that were removed from the regression analyses (as a result of contamination from portal spills). The concentration and load charts included in the report state, "Data from 01/09/95 1800 - 01/12/95 1700 omitted." This information was not considered in the SEA review.

2. The Boulder Creek Remedial Alternative Study was conducted to provide information to the Boulder Creek Peer Review Panel. As a result, some elements identified by SEA as deficient or without substantiation had been the subject of extended discussions with members of the Peer Review Panel. The Peer Review Panel expert hydrologist recognized early in the studies that the flow data reported by SMC for the Boulder Creek weirs were deficient, particularly at elevated flows. As discussed in the Boulder Creek Hydrologic Model documentation provided to SMC (Ott and Kumar, 1995, page 8, Appendix A), problems with the weirs included:

   - Head measurement devices located too close to the weir
   - Head measurement devices sometimes buried by sediment in the pools
   - High approach velocities to the weirs
   - Approach flows skewed to the weirs
   - Sediment in weir pools
   - Flume skewed to flow

   The weir deficiencies were recognized by SMC and were reported in the March 1995 stream monitoring report (SMC, 1995)

   > "Difficulties have been encountered during storm flow conditions (i.e. boulders and other debris in the inlet, loss of instrumentation).
   >
   > The weirs have not been calibrated over a range of flow rates "

   Other SMC consultants were aware of the problems with the SMC weirs. SMC's consultant Morrison Knudsen notes (page 8, 1995)

   > "The weirs at Slickrock Creek and Boulder Creek mouths were damaged during the January storms; hence some of the pertinent flow data for January, particularly during peak flow periods, were estimated by SMC based on field measurements and judgement (sic)"

In the calibration of their HEC-1 model using the "observed" SMC January 8 through 10 storm data, Morrison Knudsen states that (1995, Page 10)

> "The estimated peak discharge of the observed hydrograph was 420 cfs, corresponding to a frequency of about 5 years, and appears to be low compared to the rainfall which is more like a 10-year event."

Thus, flow measurement equipment was not operational during the two important storm events that occurred in January 1995 and March 1995. The equipment either malfunctioned or was washed out during the January 8 through 14 storm (SMC, 1995, page 4) and again during the March 9 through 11 storm. During these events SMC estimated the flows at BCMO by using the average daily inflow to Spring Creek Debris Dam (SCDD) reservoir proportioned as a function of the Boulder Creek area. (SMC, 1995, page 4). The SEA reference to SMC flow "observations" is not correct. This information was not considered in the SEA review.

Subsequent to the SMC February 2, 1995, draft submittal of early January data, SMC streamflow data reported for all sampling stations were computed using area apportionment and the SMC computed flow at BCMO. In addition, because of the many problems with the BCMO weir, it was replaced in summer 1996.

EPA agrees that only limited calibration of the HSPF model was performed in 1995. The performance of the model was compared to flow data acquired by SMC (low and moderate flows). SMC flow measurement equipment was not operational during the two high flow events of 1995. EPA evaluated the performance of the HSPF model under high flow conditions by field inspection of high water marks. EPA presented its conclusions to the BCRAS Peer Review Panel. The panel's expert hydrologist, Jack Humphrey, concluded that the HSPF model results were reliable for the purposes of the study, and that the data from SMC's weirs were deficient. Only one season of data was available at the time, so evaluation with an independent data set was not possible. The HSPF model can be further evaluated with additional data acquired since this time as part of the further Boulder Creek studies that EPA is proposing to perrform.

3. The SMC 1995 and 1996 data show that typically 15 to 25 percent of the Boulder Creek copper load originates downstream of BCW18. This amount can vary considerably and, during high-flow conditions, the load can amount to hundreds of pounds of dissolved copper discharged per day. For example, SMC reports that on February 17, 1996, the copper load at BCMO was 1,016.43 pounds, while the load upstream at BCW18 was 433.38 pounds (SMC, 1996). This variability in the computed load for the January through March 1995 period was graphically depicted in Appendix E to the *Boulder Creek Remedial Alternative Study* (U.S. EPA, 1995). This information (provided to SMC and SEA) was not considered in the SEA review.

4. The final report to the Boulder Creek Peer Review Panel, dated September 19, 1995, contained revised regression equations that incorporated all data without flow restrictions for all sampling stations. The report was provided to SMC and transmitted by SMC to SEA. The approach was clearly presented in the revised analysis together with the results of using regression equations computed for the upper and lower 90 percent

confidence intervals. The electronic data files were transmitted to SMC on October 3, 1995. This information was not considered in the SEA review.

Analysis of the December 1995 through April 1996 SMC data demonstrates that SEA's statement regarding the CH2M HILL regression equation, "Their regression equations hence overpredict the metals load in the critical high flow regime," is not correct. See the Response to SEA Conclusion 7 below for discussion pertaining to predictions of concentrations using the CH2M HILL and EPA regression equations.

5. The CH2M HILL Boulder Creek Peer Review Panel Report and the load regression equations were revised in the final report, dated September 19, 1995. The report presented regression equations in the form of copper concentration versus flow and copper load versus flow. The coefficients of determination were presented for both sets of analyses. The concentration regression coefficients ranged from a low of 0.5408 at Sampling Station BCW12 to a high of 0.6144 at Sampling Station BCLG. The regression coefficient at BCMO equaled 0.5585.

   Additional data analysis has been completed using the combined data obtained during the 1994-1995 and 1995-1996 sampling periods. That data, and the analysis of the data, were presented in the *Water Management Feasibility Study Addendum* (U.S. EPA, 1996). Analysis of data from the 1996-1997 sampling period is set forth in the technical memorandum re *Additional Water Quality Model Simulations Using Data Collected Through June 1997 and Proposed Water Quality Standards.*

6. Using a flow restriction on the data employed in the regression analysis substantially alters the regression equation coefficients and decreases the R^2. This is due in part to the relatively low number of elevated flow data points that are included in the data set.

   The SEA reference to SMC flow "observations" demonstrates that SEA was apparently misinformed about the storm flow data reported by SMC. The flow measurement equipment was not operational during the two important storm events that occurred in January 1995 and March 1995. The equipment either malfunctioned or was washed out during the January 8 through 14 storm (SMC, 1995, page 4) and again during the March 9 through 11 storm. During these events SMC estimated the flows at BCMO by using the average daily inflow to Spring Creek Reservoir proportioned as a function of the Boulder Creek area. (SMC, 1995, page 4). This information was not considered in the SEA review.

   Errors in SEA's review of the HSPF model are detailed in the technical memorandum responding to the SEA document *Critical Review of CH2M HILL's Application of EPA's Hydrologic Simulation Program FORTRAN (HSP-F) to Boulder Creek.*

7. The reference by SEA to "overpredictions" was evaluated by comparing the SMC-reported BCMO concentration and flow data for December 1995 through March 1996 with the CH2M HILL (U.S. EPA, 1995) and the SMC load regression equations (Weston, 1995). The 1995-1996 flow data are somewhat problematic in that the SMC monitoring equipment at BCMO either malfunctioned or was washed out again during high-flow conditions in the December 12, 1995, storm. Onsite SMC employees did make estimates of the flow on the basis of visual "observation," but were unable to measure the flow

velocities (for weir calibration) at the BCMO weir because of non-functioning velocity measuring equipment.

The reported concentrations and the computed regression equation concentrations were compared for flows exceeding 300 cfs and for flows in the range from 100 to 300 cfs. Also computed were the number of regression equation values that exceeded the reported values (count over), the average of the errors (difference between reported and computed values) and the standard deviation (Std. Dev.) of the errors. Table 1 provides the results of this analysis.

Analysis of the data shows that both the CH2M HILL regression equations and the SMC regression equations underpredict the reported copper concentrations associated with flows greater than 300 cfs. For flows greater than 300 cfs, the CH2M HILL load regression equation underpredicts the copper concentration for 14 of the 15 data points by an average value of -0.28 µg/L, with a standard deviation of the error of 0.15 µg/L. For this same flow range, the SMC load regression equation underpredicts the copper concentration for 15 of the 15 data points by an average value of -0.42 µg/L with a standard deviation of the error of 0.15 µg/L. For concentration data pertaining to flows ranging from 100 to 300 cfs, the average copper concentration for 43 samples equaled 0.43 µg/L, while the CH2M HILL average computed concentration equaled 0.47 µg/L with an average error of 0.04. The SMC average computed concentration equaled 0.37 µg/L with an average error of -0.06.

Table 1
SMC December 1, 1995–April 30, 1996 BCMO Flow and Copper Concentration Data Compared to SMC and CH2M HILL 1995 BCMO Load Equations

	Flow (cfs)	Avg. (µg/L)	Count (over)	Error Avg.	Error Std. Dev.
SMC 1995–1996 Data	> 300	0.66	15		
SMC 1995 Load Equation	> 300	0.24	(0)	-0.42	0.15
CH2M Load Equation	> 300	0.38	(1)	-0.28	0.15
SMC 1995–1996 Data	100 - 300	0.43	43		
SMC 1995 Load Equation	100 - 300	0.37	(29)	-0.06	0.24
CH2M Load Equation	100 - 300	0.47	(32)	0.04	0.23

Analysis of the 1995-1996 data demonstrates that the CH2M HILL regression equation underpredicts the average observed copper concentration for the critical flows greater than 300 cfs.

Summary

The SEA analysis does not consider pertainent information that was been provided by SMC, EPA, and Morrrison Knudsen pertaining to the problems encountered by SMC with measuring flows during the January through March 1995 period. The numerous SEA references in the review document to flow "observations" are not correct. The CH2M HILL load regression equations provide a better estimate of the SMC-reported copper concentrations in the high-flow regime for the period December 1995 through March 1996.

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Review of Spring Creek Reservoir Capacity

PREPARED FOR: Rick Sugarek/U.S. EPA

PREPARED BY: John Spitzley/CH2M HILL

Description of Document

This document, *Spring Creek Reservoir Capacity,* dated October 13, 1995 [SMC Vol. 32, Tab 4], was prepared for Stauffer Management Company (SMC) by Spaulding Environmental Associates (SEA). The document provides an estimate of the 1995 Spring Creek Debris Dam (SCDD) active storage volume. The active storage volume is defined as the volume available to store and release inflows to the reservoir without overtopping the spillway. The estimate uses 1995 survey data and the 1962 U.S. Bureau of Reclamation (USBR) construction drawings. The estimate also provides an analysis of the reservoir capacity using USBR flow data reported for the January 1995 storm. The results of this analysis are compared with the elevation-capacity curves used in the Iron Mountain Mine (IMM) Water Quality Model (WQM) and are used to estimate the sedimentation volume present in the reservoir area.

Major Findings or Major Review Comments in Document

SEA used survey data collected by PACE Engineering consisting of topographic data collected along sections upstream of the SCDD and bathymetric data collected using acoustic techniques in the immediate vicinity of the dam. These data were electronically combined with the 1962 topographic as-built maps produced by USBR to obtain a revised topographic contour mapping. This mapping was used to compute the present (1995) active storage volume of Spring Creek Reservoir. The results of this effort were evaluated using the USBR January 1995 reservoir inflow and release data. Major findings of the report include the following:

- Sedimentation has occurred in the immediate vicinity of the reservoir with a maximum depth of 60 feet. The present reservoir (land surface) bottom is located at Elevation 694. USBR's as-built capacity profile provides a capacity of 5,390 acre-feet at Elevation 694.

- The total amount of sedimentation is estimated at 426 acre-feet, or approximately 14.2 acre-feet per year (over approximately 30 years of operation).

- The present storage capacity of the reservoir is 5,454 acre-feet, 438 acre-feet larger than the 5,016 acre-feet stated by CH2M HILL in the IMM WQM (*IMM Water Quality Model,* U.S. EPA, 1994).

- The analysis of USBR's January 1995 flow data concluded that the storage capacity of the reservoir is between 5,194 and 5,395 acre-feet.

Response to Major Findings in Document

1. The SEA analysis computes a reservoir storage volume of 5,454 acre-feet assuming that the dead pool is located below Elevation 694. This assumption is not correct. According to USBR's Central Valley Operations (Fujitani, 1996a) the active storage area is located above Elevation 701.3, corresponding to the top of the lower outlet louver. Except for maintenance, USBR operates Spring Creek Reservoir above Elevation 701.3 to help decrease sediment and debris plugging at the outlet. Neither the Central Valley Operations office (Fujitani, 1996a) nor the Northern California Area office (Gibbons, 1996) are aware of requests from SMC, SEA, or PACE Engineering for access to the site for surveying, or requests for information pertaining to the elevation of the dead pool or the active storage volume.

2. The PACE bathymetric data indicate that water was present in the reservoir at Elevation 704.56 (Page 21, Point # 268) in August 1995. This reservoir elevation at the middle or end of the summer should have been an indicator that the elevation of the dead pool does not correspond to Elevation of 694.

3. Previous USBR determinations of sediment deposition were based on average end area analysis; the SEA analysis computed volumes integrating areas between contours. In order to provide a comprehensive review, the area-capacity tables generated by SEA for the 1995 topography and the original topography should be provided.

4. The reservoir elevation-capacity curve used in the IMM WQM (U.S. EPA, 1994) was provided by USBR in 1993. The area-capacity data were generated by USBR in July 1993.

5. In reference to the original USBR area and capacity versus elevation table reprinted in Table 1-1 of the subject document, SEA states that "SEA's analysis procedure, applied to the as-built design, successfully reproduced the results in Table 1-1 to within 2 to 4%." SEA does not provide the recalculated tables, so it is uncertain as to which elevation the 2 to 4 percent error applies. The error in the SEA calculation at Elevation 795 (original 5,880 acre-feet) could range from 117.6 (at 2 percent) to 235.2 acre-feet (at 4 percent). This equates to 25 to 50 percent of the differential volume that SEA claims is available in storage if IMM continues to contaminate Spring Creek watershed waters.

6. The January 1995 storm analysis uses USBR inflow and outflow data as a check on the computed reservoir capacity. Because the data used by SEA are not provided in the report, it is not possible to check the calculations or the data. Analysis of the Spring Creek Debris Reservoir Daily Operations report provided by USBR for January 1995 (attached) indicates discrepancies between the results computed using USBR data and the results presented by SEA. Table 1 provides a listing of the daily SCDD inflow and releases reported by USBR and the total cumulative storage volumes using the initial storage volume of 373.6 acre-feet assumed in the SEA analysis.

   SEA reported reservoir volumes of 5,194 acre-feet and 5,711 acre-feet on January 11 and 12, respectively; and reservoir volumes of 5,395 acre-feet and 4,884 acre-feet on January 15 and 16, respectively. Inspection of the computed volumes in Table 1 shows a slight difference between the SEA reported volumes and the volumes computed using USBR data. For instance, on January 11, SEA reports a volume of 5,194 acre-feet, while Table 1 lists a value of 5,180 acre-feet. Because SEA does not provide the data used in its analysis, the reason for this discrepancy is unknown.

Because the SEA analysis incorrectly assumes a dead pool elevation of 694, the SEA initial January 1, 1995, storage volume of 373.6 acre-feet is not correct. Using a dead pool elevation of 701.3, and assuming that the volume is proportional to small changes in elevation, an initial January 1, 1995, storage volume of 180 acre-feet was calculated. This corrected initial volume was used to recalculate the SCDD cumulative storage volumes listed in Table 1.

Table 1
USBR Daily SCDD Operations Reports and Storage Calculations

Date	Inflow (cfs)	Release (cfs)	Inflow (ac-ft)	Release (ac-ft)	Cumulative Storage (ac-ft)	Cumulative Storage (ac-ft)
Initial					**373.6**	**180**
1/1/95	2	10	4	20	358	164
1/2/95	-1	10	-2	20	336	142
1/3/95	0	10	0	20	316	122
1/4/95	33	10	65	20	362	168
1/5/95	15	10	30	20	372	178
1/6/95	27	10	54	20	405	212
1/7/95	282	10	559	20	945	751
1/8/95	832	10	1,650	20	2,575	2,382
1/9/95	1,484	320	2,943	635	4,884	4,690
1/10/95	342	320	678	635	4,928	4,734
1/11/95	527	400	1,045	793	5,180	4,986
1/12/95	1,087	826	2,156	1,638	5,697	5,504
1/13/95	1,023	931	2,029	1,847	5,880	5,686
1/14/95	737	842	1,462	1,670	5,671	5,478
1/15/95	185	332	367	659	5,380	5,186
1/16/95	117	375	232	744	4,868	4,675

Initial 180-acre-foot storage volume calculated using dead pool Elevation 701.3.

Using the corrected dead pool elevation of 701.3 and the corresponding initial January 1, 1995, storage of 180 acre-feet results in a decrease in the estimated SCDD active storage volume. The computed reservoir storage was 4,986 acre-feet the day before the SCDD spill on January 11, 1995. On January 12th, the first day of the spill, the reservoir storage was estimated at 5,504 acre-feet. Note: this storage volume includes the volume above the spillway sill elevation. From this calculation, the storage volume is greater than 4,986 acre-feet but less than 5,504 acre-feet. On the last day of the spill (January 15) the volume was estimated at 5,186 acre-feet, decreasing to 4,675 acre-feet on January 16th. From this calculation the volume was greater than 4,675 acre-feet and less than 5,186 acre-feet. Taken together, the volumes immediately before and immediately after the spill provide a reservoir volume estimate between 4,986 acre-feet and 5,186 acre-feet. The analysis using the corrected dead pool elevation indicates that the assumption of 5,016 acre-feet used in the IMM WQM, is reasonable.

The analysis provided in Table 1 makes use of USBR's daily operations data. As reported in the *Water Management Feasibility Study Addendum* (U.S. EPA, 1996), additional analyses of the actual flows were completed using the bihourly flow measurements reported by USBR (Fujitani, 1996b) for the period January 9, 1995, to January 16, 1995. USBR's January 1995 bihourly flow data are attached to this memorandum. Analysis of these bihourly data shows that the initial operations data reported in the Spring Creek Debris Reservoir Daily Operations report overestimated SCDD inflows and releases. Table 2 lists the average daily flows computed using USBR's bihourly flow data for the period, together with the daily operations data for the January 1, 1995, through January 8, 1995, period. Also listed in Table 2 is the cumulative storage volume computed assuming an initial January 1, 1995, storage of 180 acre-feet, corresponding to a dead pool elevation of 701.3.

Table 2
USBR SCDD Operations Reports and Storage Calculations
Daily Data January 1 - 8, 1995; Bihourly data January 9 -16, 1995

Date	Inflow (cfs)	Release (cfs)	Inflow (ac-ft)	Release (ac-ft)	Cumulative Storage (ac-ft)
Initial					**180**
1/1/95	2	10	4	20	164
1/2/95	-1	10	-2	20	142
1/3/95	0	10	0	20	122
1/4/95	33	10	65	20	168
1/5/95	15	10	30	20	178
1/6/95	27	10	54	20	212
1/7/95	282	10	559	20	751
1/8/95	832	10	1,650	20	2,382
1/9/95	1,232.8	71.0	2,445	141	4,686
1/10/95	374.3	319.8	742	634	4,794
1/11/95	447.1	395.7	887	785	4,896
1/12/95	671.1	396.4	1,331	786	5,441
1/13/95	539.8	508.6	1,071	1,009	5,503
1/14/95	549.7	618.4	1,090	1,227	5,366
1/15/95	240.6	371.4	477	737	5,107
1/16/95	118.5	373.8	235	741	4,601

As shown in Table 2, the reservoir volume was 4,896 acre-feet on January 11, 1995 (the day before the spill). On January 12th, the first day of the spill, the reservoir volume was estimated at 5,441 acre-feet. From this calculation, the volume is greater than 4,896 acre-feet but less than 5,441 acre-feet. On the last day of the spill (January 15), the volume was estimated at 5,107 acre-feet, decreasing to 4,601 acre-feet on January 16th. From this calculation the volume is greater than 4,601 acre-feet and less than 5,107 acre-feet. Taken together, the volumes immediately before and immediately after the spill provide an estimated reservoir volume between 4,896 acre-feet and 5,107 acre-feet. The analysis using the bihourly flow data indicates that the assumption of a 5,016-acre-foot reservoir used in the IMM WQM is reasonable.

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Review of Iron Mountain Mine Slickrock Creek Retention Pond Sizing

PREPARED FOR: Rick Sugarek/U.S. EPA

PREPARED BY: Ken Iceman/CH2M HILL

Description of Document

This document, *Iron Mountain Mine Slickrock Creek Retention Pond Sizing* (Morrison Knudsen Corporation, February 10, 1995), discusses the hydrologic basis for the design capacity of the Slickrock Creek retention pond. The development of the storm runoff, baseflow, and pond water balance are provided for two pond sizes, 115 acres and 140 acres, to estimate the maximum storage required.

Local rainfall data at the site and historic precipitation records at Shasta Dam were used in the database development. No long-term records at the site were available.

Major Findings or Major Review Comments in Document

1. The methodology followed the Soil Conservation Services (SCS) approach using historic and regional accumulated rainfall distributions to develop runoff hydrographs and net pond capacities for two antecedent moisture conditions (AMC II and AMC III).
2. The resultant findings of the retention pond sizing analyses showed that a 165- to 220-acre-foot retention pond would be required, assuming a 24-hour continuous discharge of 1,700 gpm to the outlet pipeline (supply to the treatment facility), a 100-year, 30-day storm event, and a 140-acre drainage area. No specific capacity was recommended, and freeboard or emergency outlet works were not mentioned.
3. The sizing analysis assumed a continuous 24-hour release from the pond into the outlet pipe of from 1,700 gpm to 3,200 gpm.
4. The pond was assumed to be empty at the start of the storm event.

Response to Major Findings in Document

Response to Finding 1

The hydrologic approach appears reasonable and follows the SCS methodology to account for varied soil types, ground cover, and antecedent moisture conditions.

The analysis assumes that each of the four historical events was accurately analyzed by using the AMC II curve numbers. This could be misleading in that the historic storms may have followed prior wet periods, in which case the AMC III condition would be more appropriate. If so, the required storage for the historical events would have exceeded the projected 100-year, 30-day event.

In modeling the required pond size, the historic storms and the hypothetical 100-year, 30-day storm should have used the AMC III condition to determine the range of possible capacities. The comparison of the historic storm capacities with the 100-year, 30-day storm would be a valuable measure for the design pond size.

Response to Finding 2

The report does not recommend a pond size. The report also assumes that the discharge from the pond is continuous. This assumption fails to account for problems during operation with the outlet gate, pipeline, or treatment plant. Since these problems will inevitably occur, the maximum pond capacities are undersized.

Several detailed water balance spreadsheets for the pond sizing have inconsistent time descriptions, skipping days. The computations for outflow volume and remaining pond storage appear correct, but the time (in days) for the pond evacuation is incorrect because the time description has skipped days.

Response to Finding 3

The pond sizing depends heavily on the continuous discharge of between 1,700 gpm and 3,200 gpm. The analysis did not mention freeboard or allowance for downtime of the outlet works or pipeline.

Because the historical events show net runoff values between 160 and 275 acre-feet for a specific storm, the inability to discharge for a short period of time could surcharge the pond.

Response to Finding 4

Assuming the pond is empty at the beginning of the storm may underestimate the required pond capacity. The time of evacuation shown in the Table 2 and 3 results of the report show that several days are needed depending on the outflow rate and maximum pond volume. The design analysis should examine the pond water balance with initial conditions of the pond at 25-percent, 50-percent, and 75-percent full in order to cover a range of possibilities for operation. Problems with the outlet works, pipeline, and treatment plant coupled with the hydrology of the area make the assumption of the pond starting empty a real uncertainty.

Slickrock Creek Dam Sizing Evaluation Iron Mountain Mine

PREPARED FOR: Rick Sugarek/U.S. EPA

PREPARED BY: John Spitzley/CH2M HILL
Kim Hanagan/CH2M HILL

Introduction

This technical memorandum presents the results of our preliminary Slickrock Creek Dam Sizing Evaluation. A final detailed analysis will be completed during design. The evaluation addresses the capacity requirements for treatment and storage of acid mine drainage (AMD) discharging from the Slickrock Creek basin at Iron Mountain Mine (IMM).

The analysis shows that the reservoir size required for retention of AMD is most dependent on the area contributing to the reservoir inflow. Reduction of the inflow area through the construction of clean water diversions will be a necessary component to the design process to minimize the size of the proposed reservoir.

The analysis uses Spring Creek Debris Dam (SCDD) inflow records and area apportionment to estimate the daily flow that will be captured by the proposed Slickrock Creek Retention Dam and treated at the expanded Minnesota Flats treatment plant. The SCDD inflow records consist of U.S. Bureau of Reclamation (USBR) data for the period October 1951 through March 1996. The records prior to October 1965 were estimated by the USBR using Clear Creek gage station data. The records after October 1965 were calculated by the USBR using the stage and release data at SCDD.

The analysis was performed using an EXCEL spreadsheet constructed specifically for these evaluations. The computations are consistent with those previously reported during technical meetings with EPA and Stauffer Management Company (SMC). The spreadsheet is programmed as a simple water mass balance model that stores or discharges the computed AMD inflow. If the assumed treatment capacity is exceeded, the model stores the computed inflow until the inflow is smaller than the treatment capacity. The model then discharges the stored flow to the treatment plant. If the accumulated inflow exceeds the assumed storage and treatment capacity, the flow is spilled.

The spreadsheet is constructed so that the user may vary the area apportionment factor, the treatment capacity, or the storage volume. These terms are discussed in the next section. The model computes the exceedance discharges for the given set of conditions and computes the maximum storage required for no spills during the period of record. For the purpose of this preliminary evaluation, output for nine major storm events that occurred in the Spring Creek Watershed were recorded.

Treatment Capacity

The Minnesota Flats high density sludge (HDS) treatment plant has the capacity to treat flows from the Richmond and Lawson portals and the Old/No. 8 Mine Seep. EPA's Water Management Feasibility Study Addendum (WMFSA) details the modifications necessary to upgrade the treatment plant to handle additional dilute AMD flows. The process is hydraulically constrained at several locations including the pipeline from Slickrock Creek, the treated discharge capacity, and other intermediate points within the treatment plant. The preliminary evaluation of the existing Slickrock Creek pipeline indicated that the pipeline has a capacity of between 2,500 and 3,500 gallons per minute (gpm). Because of the extreme peaking nature of the watershed, it may not be possible to take advantage of higher flow capacity because of the need to ramp up the treatment system. For the purpose of this evaluation, a treatment capacity ranging from 1,000 gpm to 4,000 gpm was used in the analyses.

Area Apportionment

The WMFSA presents sections of Weston's Focused Feasibility Study (FFS) showing results of field investigations completed by SMC and Weston. These analyses indicate that the area contributing to the proposed reservoir ranges from about 109 to more than 150 acres. These contributing areas do not include the contaminated flows discharged from Brick Flat Pit or from the area adjacent to Catfish Pond, upstream from the Catfish Diversion. The Catfish Pond area was previously identified as a tailing pond by Kinkle, Hall, and Albers (U.S. Geological Survey Professional Paper 285). The AMD flows from these areas are relatively low, but additional work needs to be completed to address the potential for metals reduction of these discharges. Additional work also needs to be completed for diverting possibly contaminated discharges away from the hematite piles. The total Spring Creek watershed above SCDD is approximately 9784 acres. For the purpose of this evaluation, area apportionment values ranging from 1 percent (about 100 acres) to 2 percent (about 200 acres) of the Spring Creek watershed were used to compute AMD inflows.

Results of Analyses

The maximum required storage for each set of assumed conditions is presented in Table 1 and graphically in Figure 1. These storages, combined with the assumed treatment capacities, provided full treatment of all computed AMD inflows. The analyses assumed zero treatment plant downtime. For reference purposes, a Slickrock Creek Dam storage of 170 acre-feet was used for the cost evaluations presented in the WMFSA.

TABLE 1
Required Storage Volume (acre-feet)

Treatment Capacity (gpm)	Watershed Area (Percent of Total Watershed Above SCDD)			
	1.00 Percent	1.25 Percent	1.50 Percent	2.00 Percent
1,000	303	455	608	916
2,000	100	154	303	605
3,000	68	108	149	304
4,000	41	77	118	199

Table 2 summarizes what the maximum average daily inflows would be to the Slickrock Creek Dam for inflows identical to inflows during nine of the major storms since 1951, as a function of watershed drainage and area apportionment. These analyses will be useful in evaluating additional storage that may be required to accommodate treatment plant downtime.

TABLE 2
Maximum Daily Inflow to Slickrock Creek Dam (acre-feet)

	Watershed Area (Percent of Total Watershed Above SCDD)			
Storm Event	*1.00 Percent*	*1.25 Percent*	*1.50 Percent*	*2.00 Percent*
January 1970	31	39	47	62
January 1974	44	55	66	88
March 1974	31	39	47	62
January 1978	34	42	50	67
February 1983	38	48	57	76
March 1983	35	44	53	70
February 1986	20	25	30	40
January 1995	41	52	62	82
March 1995	36	45	55	73

The complete results of the sizing analyses for the nine major storms listed in Table 2 are presented in Figure 2. This figure shows the variation of the maximum required storage to accommodate inflows for each of the storms as a function of the assumed drainage areas and the treatment capacities. (The storm records used in the analyses are presented in Figures 4 through Figure 12. These figures show the average daily inflows and the cumulative inflows assuming watershed apportionments of 1.25 and 1.5 percent.) Figure 2 shows that either the March 1983 or March 1995 storm events require the largest reservoir storage volume for all scenarios evaluated.

The frequency of these nine major inflow events was estimated by performing a statistical analysis of SCDD inflow data for October 1951 through March 1996. The annual maximum inflow series for different duration events, ranging from 1 day to 20 days, were analyzed using the U. S. Army Corps of Engineers Flood Frequency Analysis (FFA) software package. FFA uses the log-Pearson Type III frequency distribution for frequency analysis. Figure 3 presents the inflow-duration-frequency curves for the various duration events evaluated.

Table 3 summarizes the return period of the inflows to the Spring Creek Debris Dam for various duration events for nine major storms. In general, the various duration inflows for the nine storms will likely occur every 10 to 30 years.

TABLE 3
Return Period of SCDD Inflows During Nine Major Storms (Years)

Storm Event	1-day	2-day	3-day	5-day	10-day	20 day
January 1970	10	10	16	10	10	21
January 1974	23	14	12	11	7	5
March 1974	10	13	11	12	10	8
January 1978	11	16	22	20	17	17
February 1983	15	6	11	10	8	12
March 1983	12	5	21	26	27	31
February 1986	4	5	6	9	8	7
January 1995	18	25	17	25	30	23
March 1995	13	21	20	26	34	27

The March 1983 and March 1995 inflow events are two of the three largest 3-, 5-, 10-, and 20-day events. These longer duration events, rather than the one and 2-day events, cause the required Slickrock Creek Dam storage to increase.

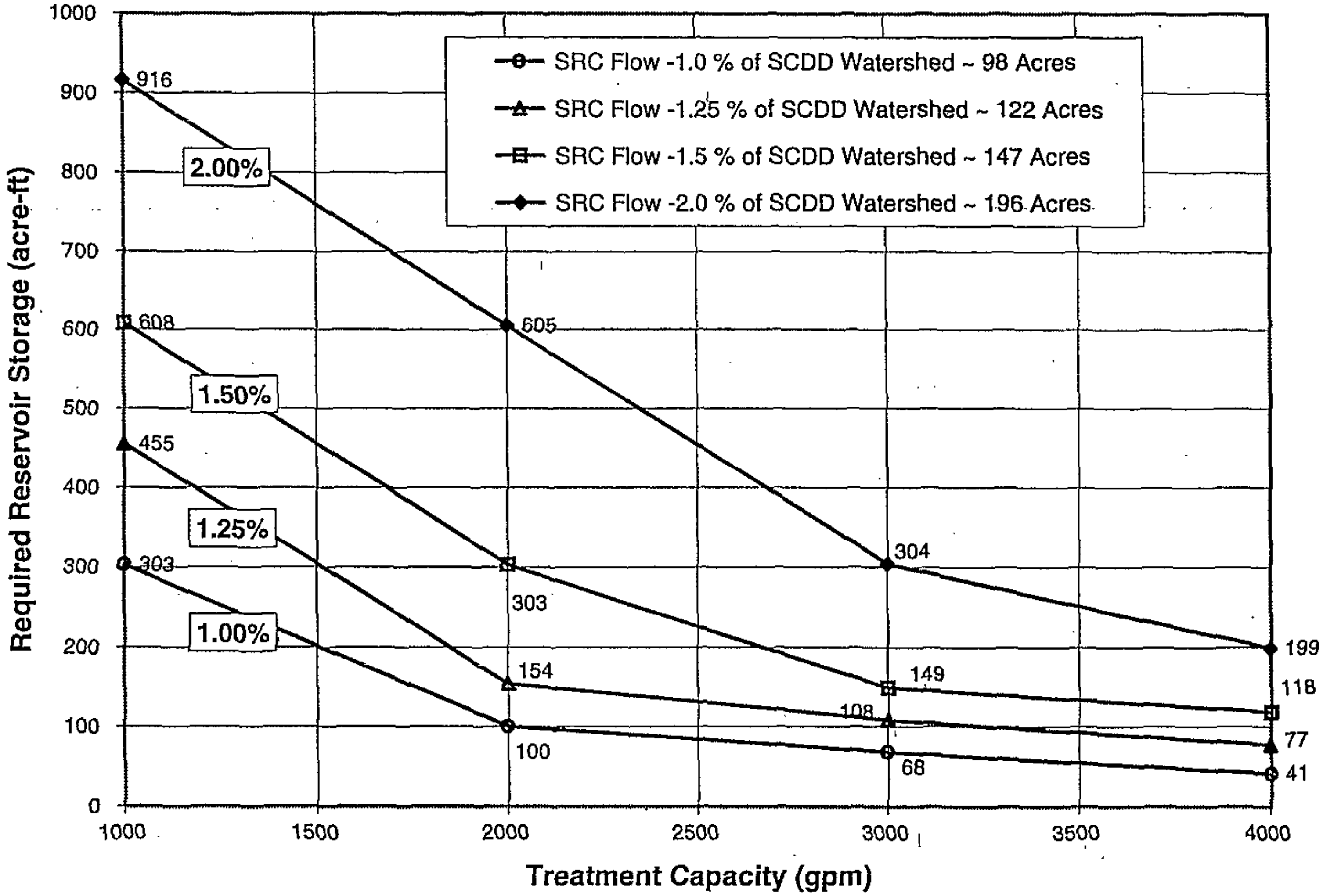

Figure 1
Required Reservoir Storage
Vs. Treatment Capacity
Slickrock Creek Dam Sizing Evaluation

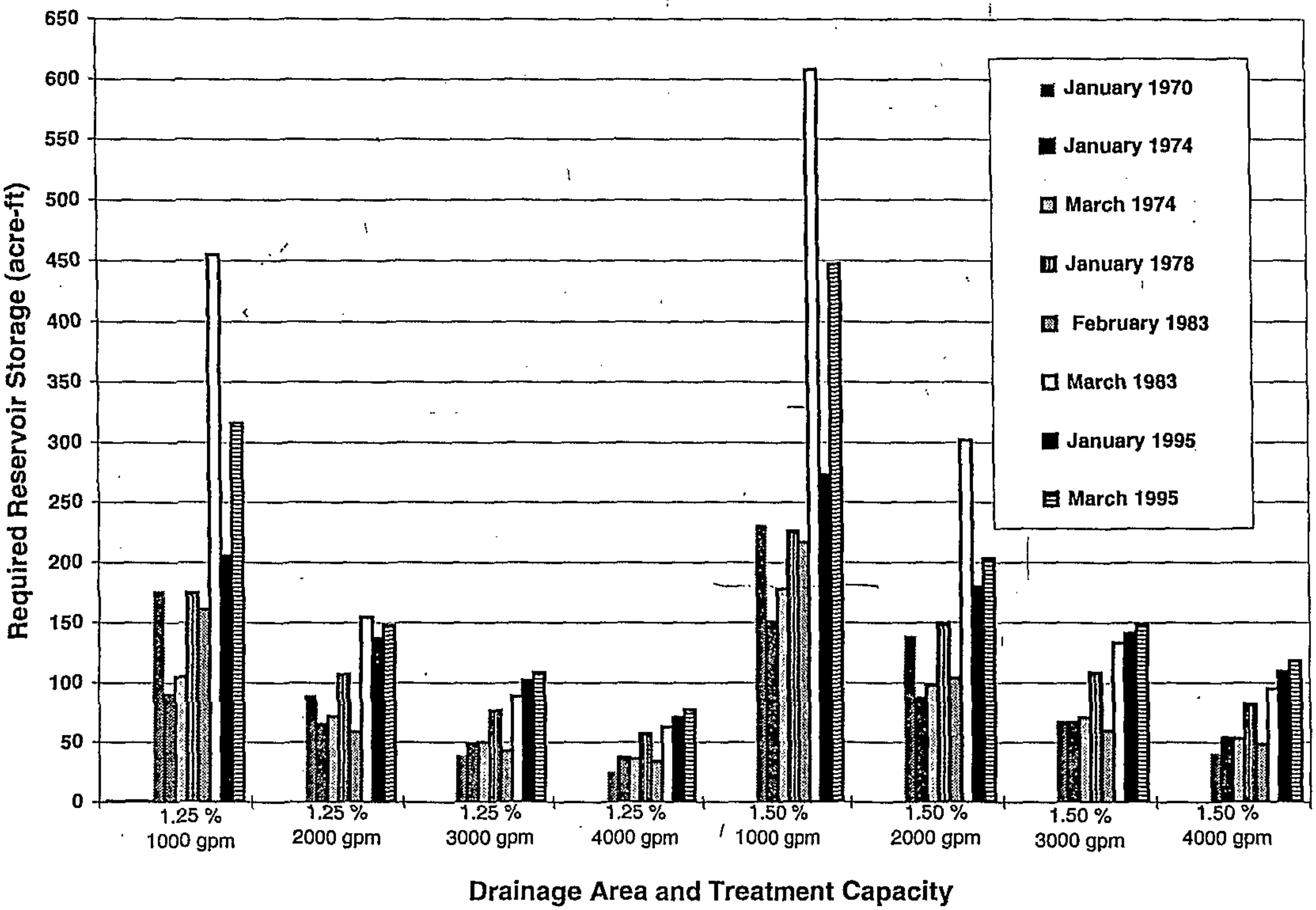

Figure 2
Required Reservoir Storage Vs. Treatment Capacity and Drainage Area
Slickrock Creek Dam Sizing Evaluation

TREATSCR.XLS: PLOT2

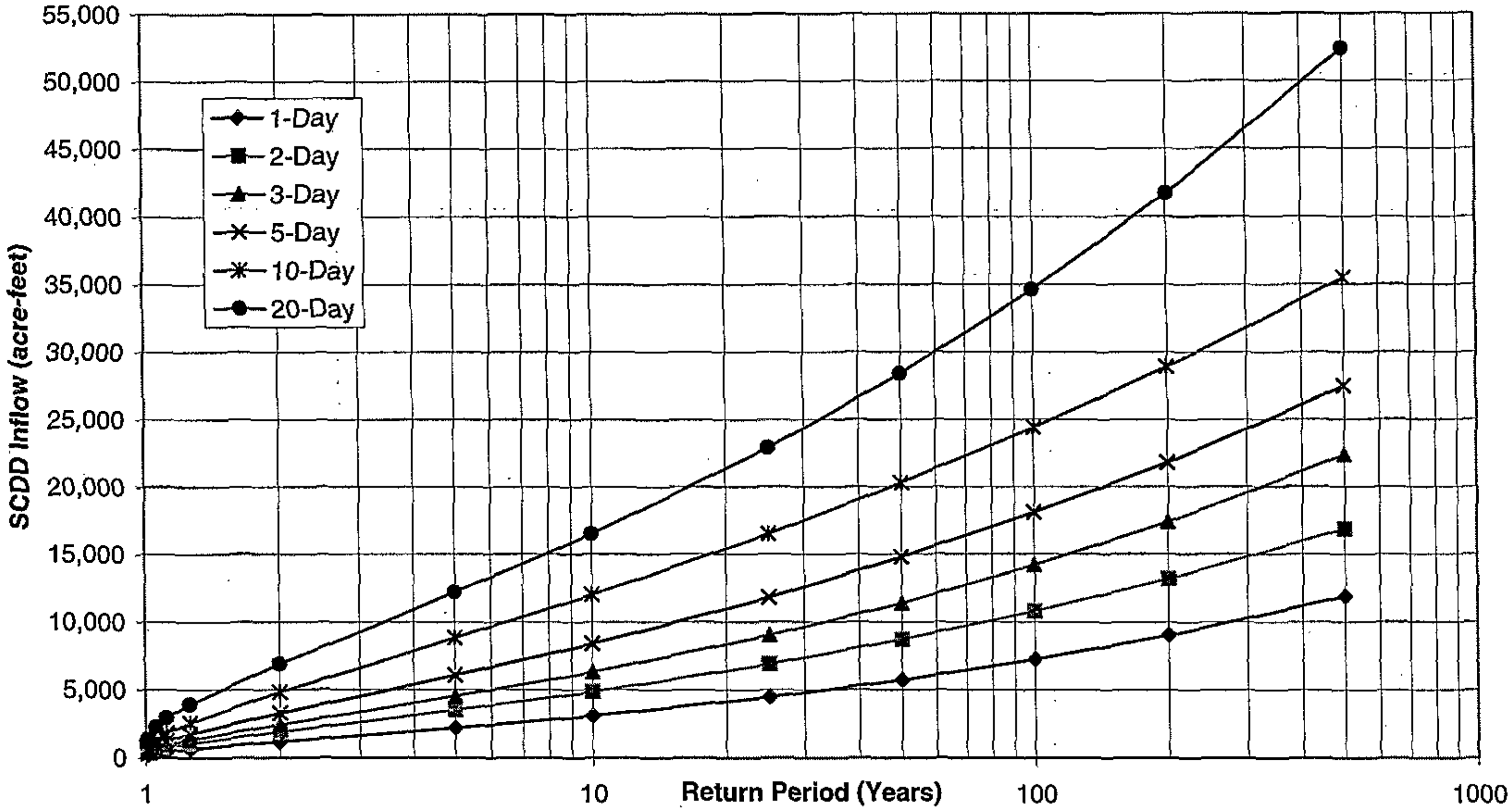

FIGURE 3
INFLOW-DURATION-FREQUENCY CURVE FOR SCDD INFLOW SLICKROCK CREEK DAM SIZING EVALUATION

SLICKROCK CREEK DAM SIZING EVALUATION
IRON MOUNTAIN MINE, REDDING, CALIFORNIA

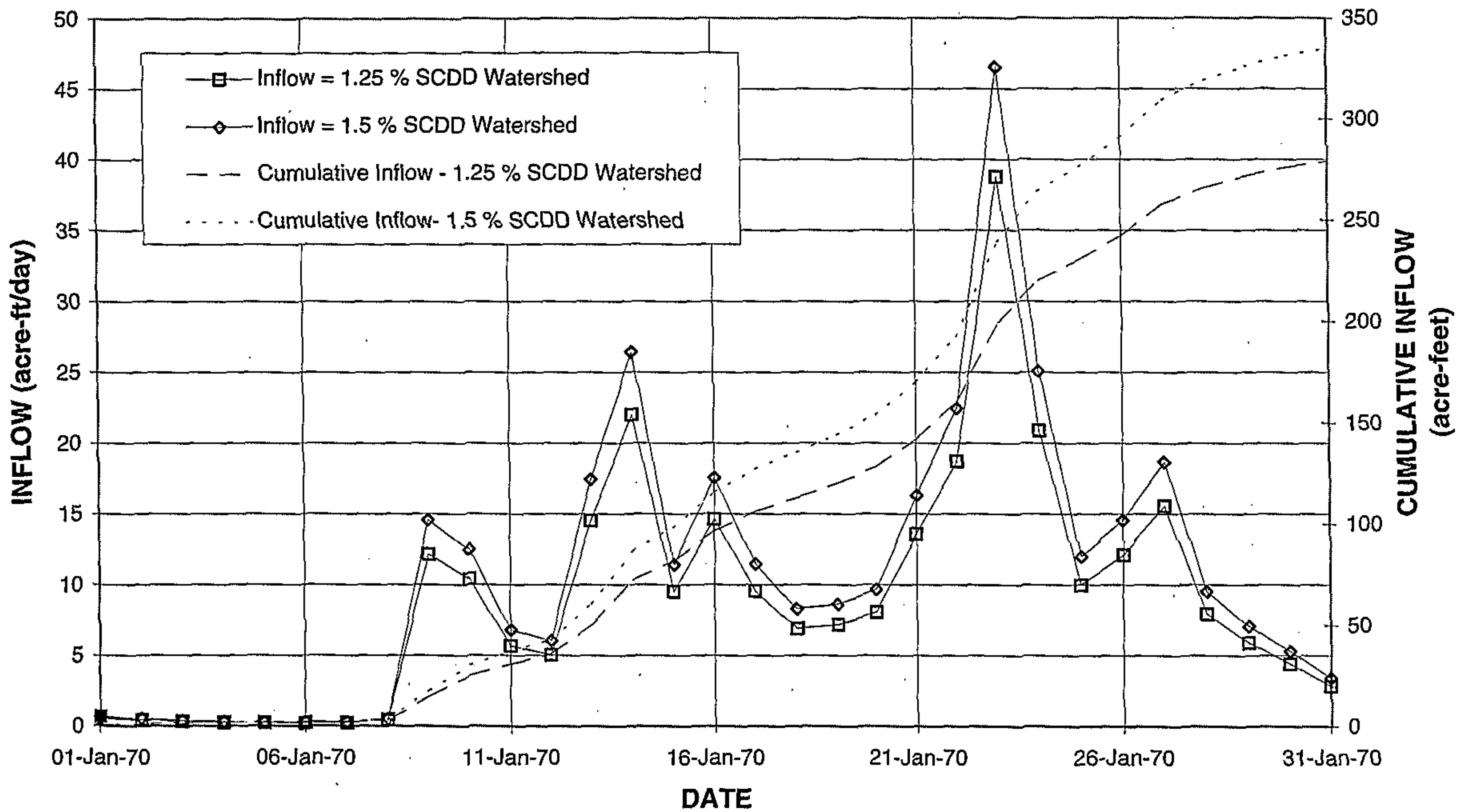

FIGURE 4
JANUARY 1970 STORM
ESTIMATED SLICKROCK DAM INFLOW
SLICKROCK CREEK DAM SIZING EVALUATION
IRON MOUNTAIN MINE, REDDING, CALIFORNIA

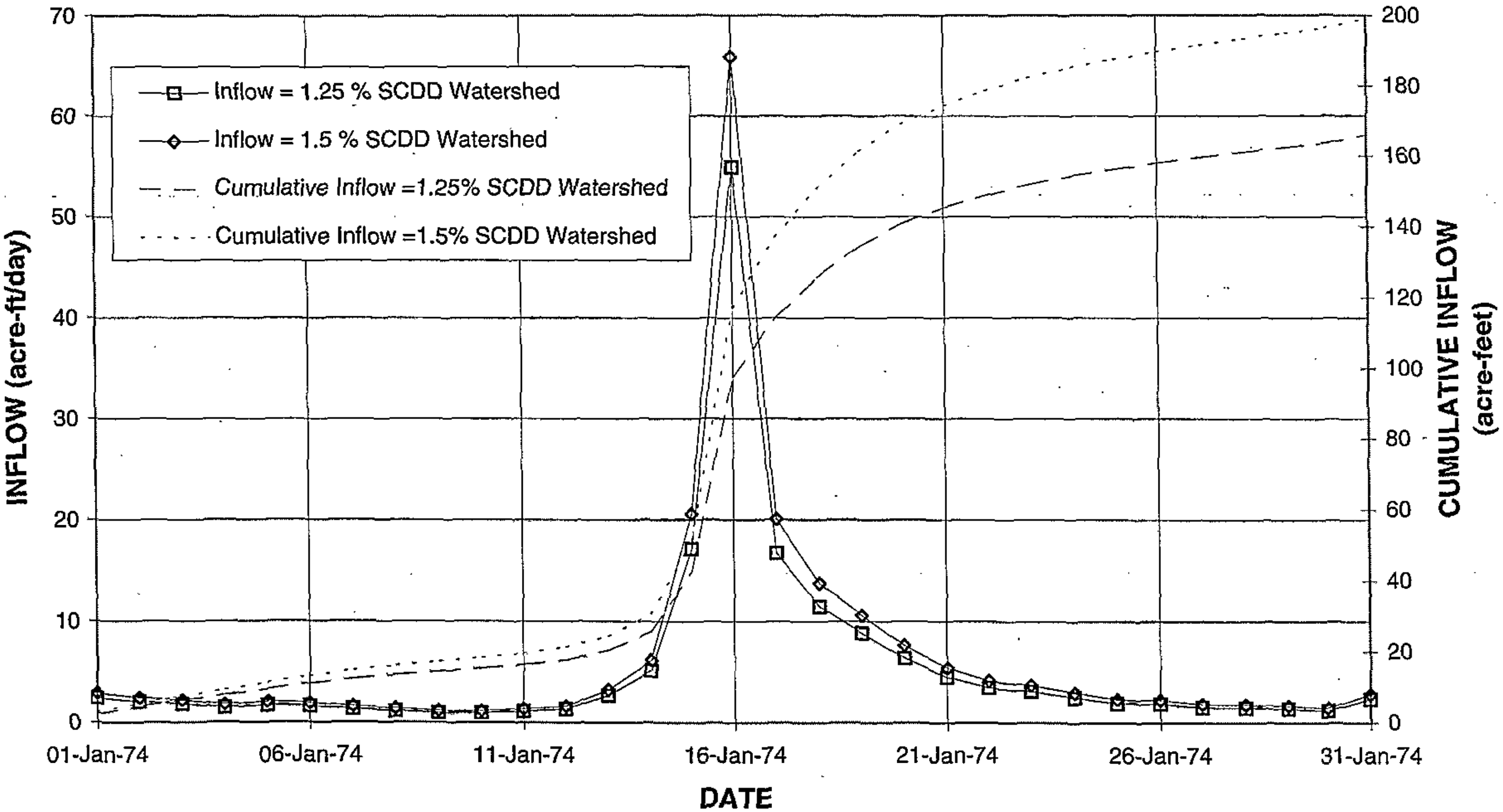

FIGURE 5
JANUARY 1974 STORM
ESTIMATED SLICKROCK DAM INFLOW
SLICKROCK CREEK DAM SIZING EVALUATION
IRON MOUNTAIN MINE, REDDING, CALIFORNIA

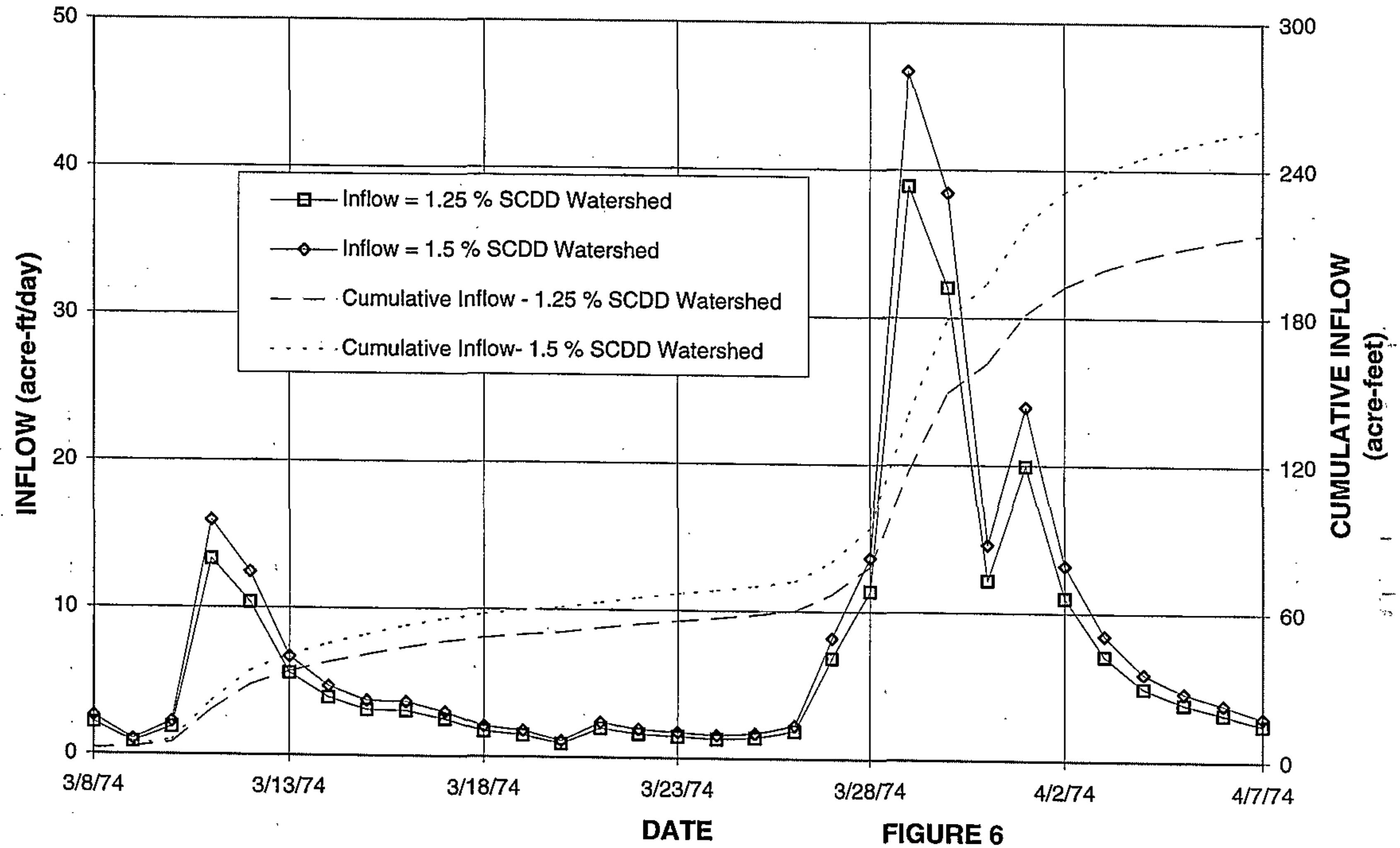

FIGURE 6
MARCH 1974 STORM
ESTIMATED SLICKROCK DAM INFLOW
SLICKROCK CREEK DAM SIZING EVALUATION
IRON MOUNTAIN MINE, REDDING, CALIFORNIA

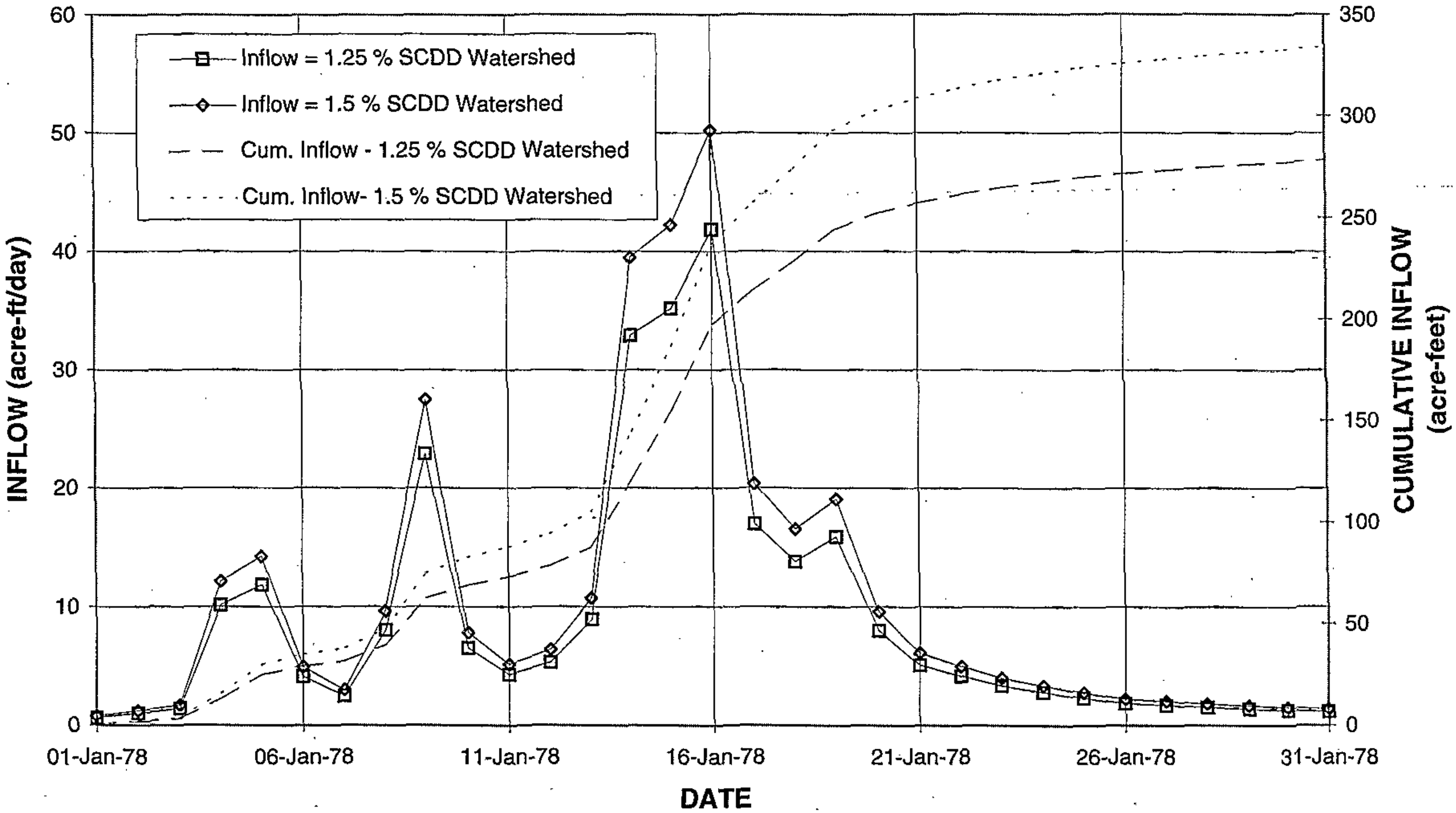

FIGURE 7
JANUARY 1978 STORM
ESTIMATED SLICKROCK DAM INFLOW
SLICKROCK CREEK DAM SIZING EVALUATION
IRON MOUNTAIN MINE, REDDING, CALIFORNIA

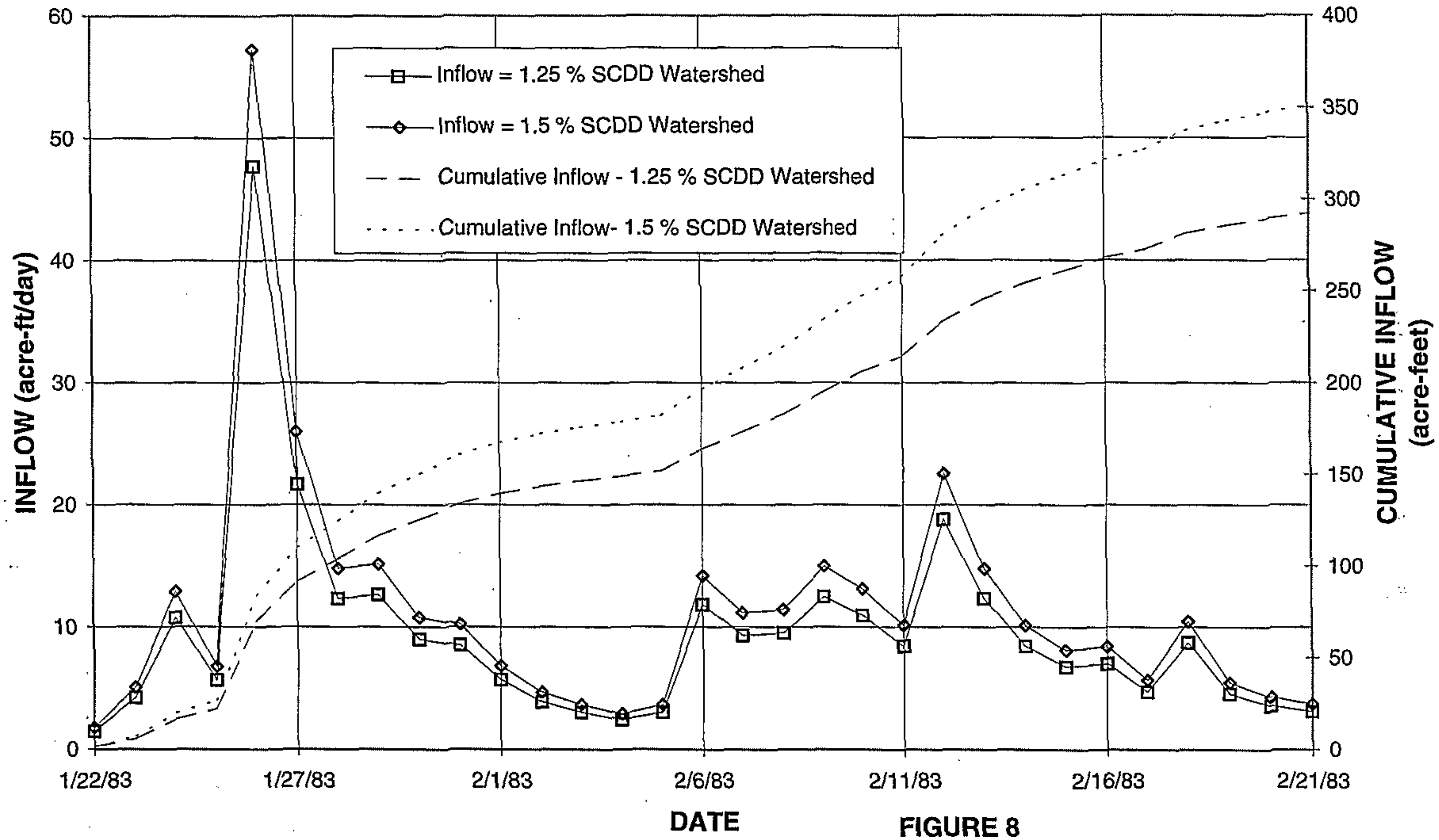

FIGURE 8
FEBRUARY 1983 STORM
ESTIMATED SLICKROCK DAM INFLOW
SLICKROCK CREEK DAM SIZING EVALUATION
IRON MOUNTAIN MINE, REDDING, CALIFORNIA

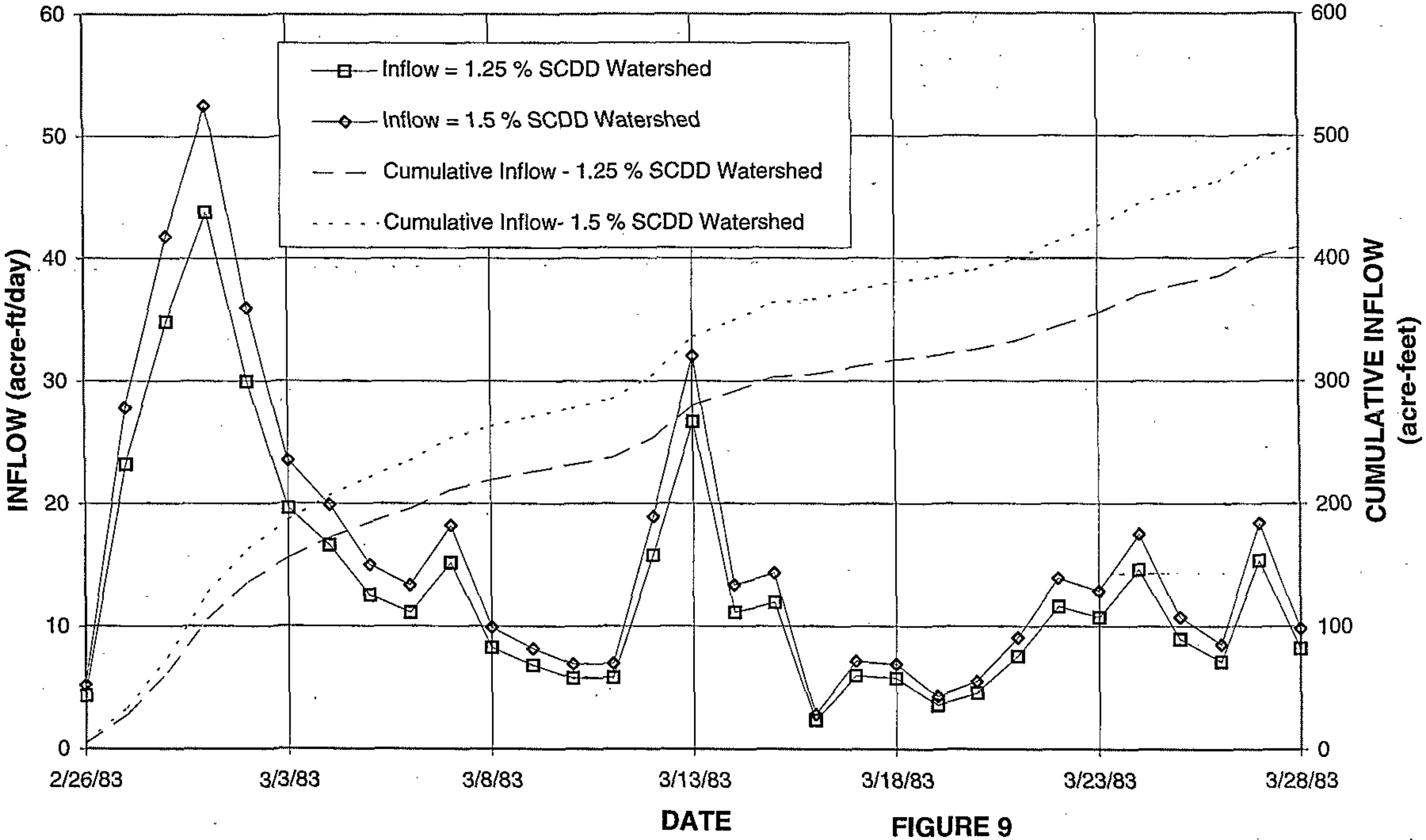

FIGURE 9
MARCH 1983 STORM
ESTIMATED SLICKROCK DAM INFLOW
SLICKROCK CREEK DAM SIZING EVALUATION
IRON MOUNTAIN MINE, REDDING, CALIFORNIA

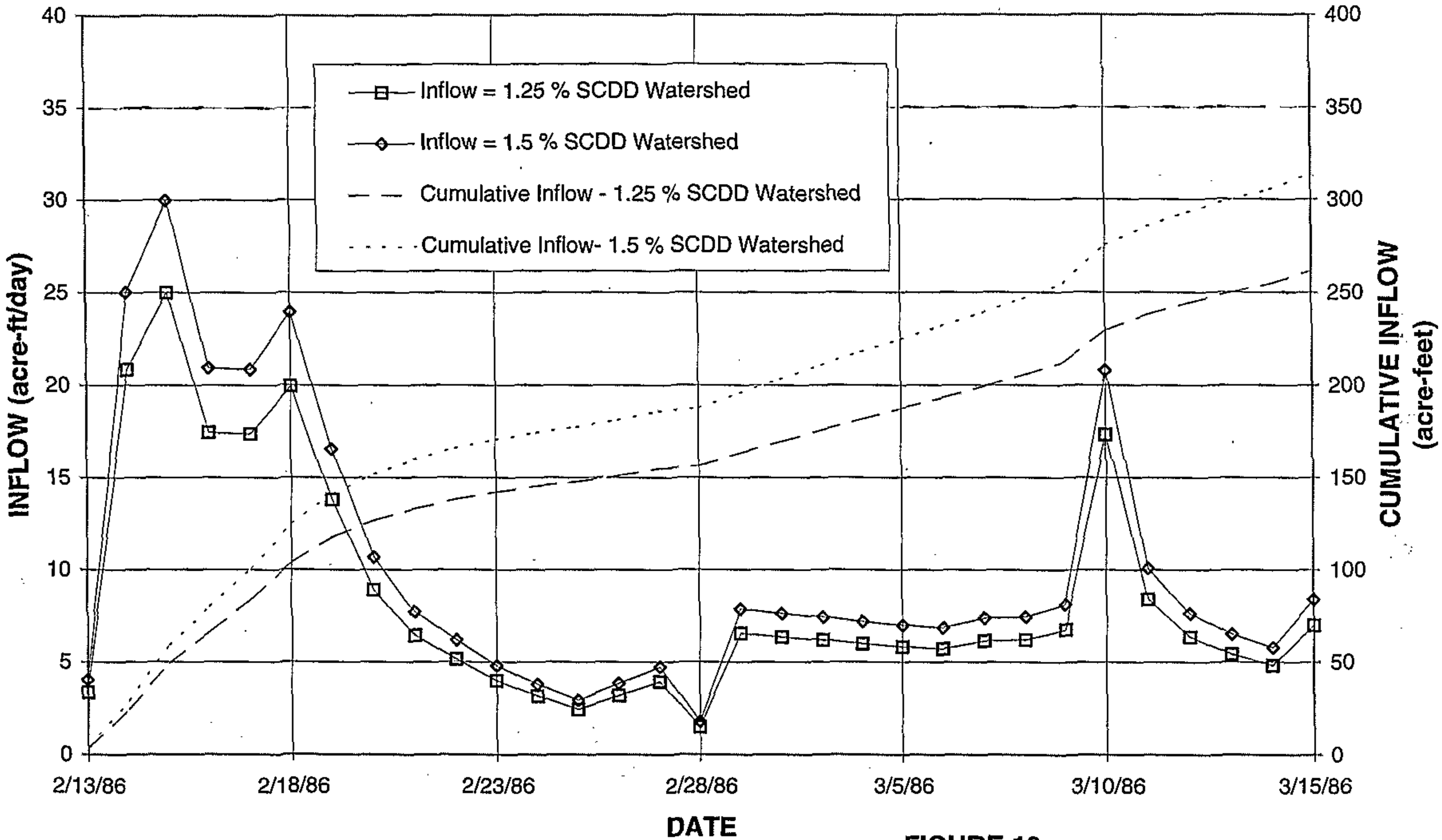

FIGURE 10
FEBRUARY 1986 STORM
ESTIMATED SLICKROCK DAM INFLOW
SLICKROCK CREEK DAM SIZING EVALUATION
IRON MOUNTAIN MINE, REDDING, CALIFORNIA

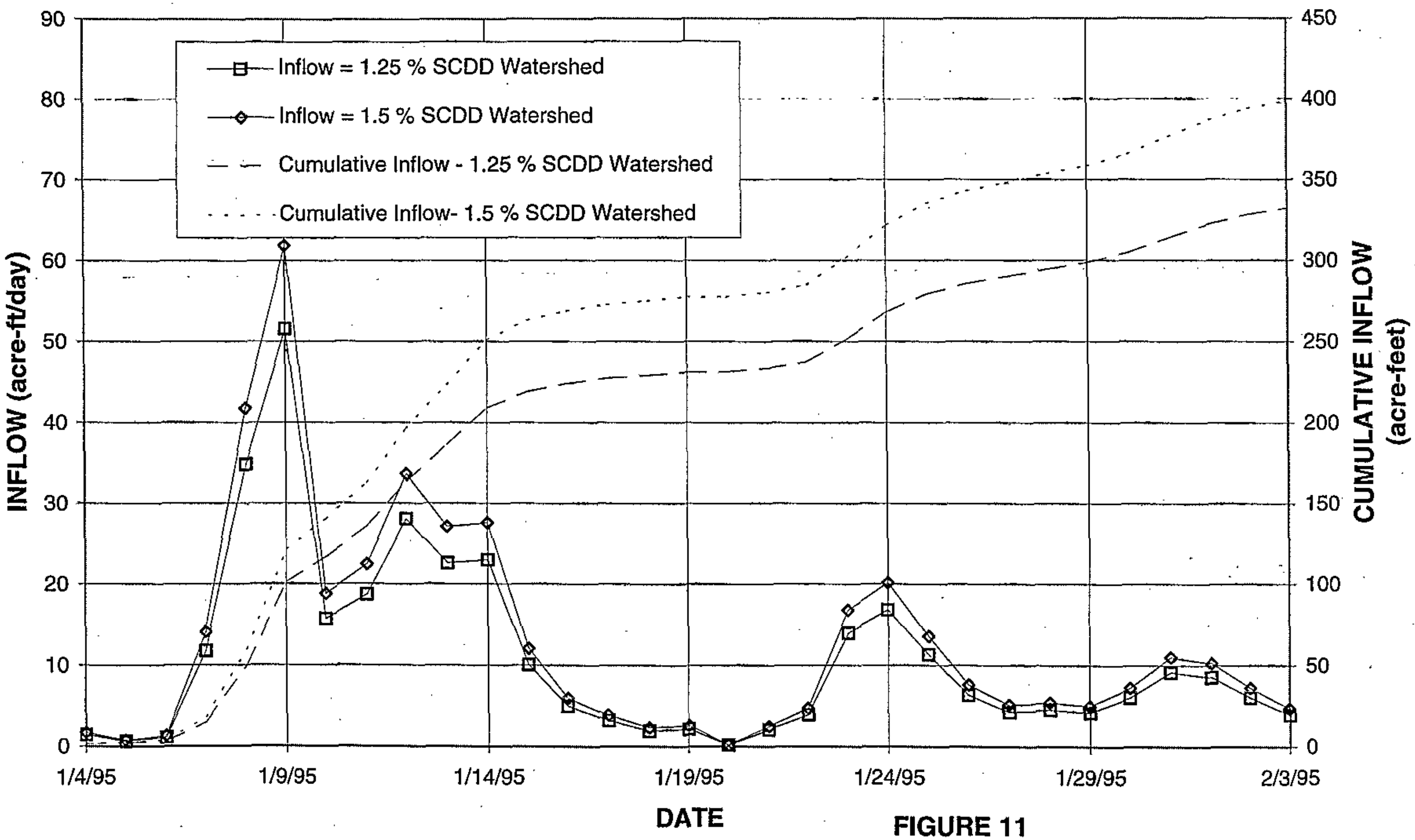

FIGURE 11
JANUARY 1995 STORM
ESTIMATED SLICKROCK DAM INFLOW
SLICKROCK CREEK DAM SIZING EVALUATION
IRON MOUNTAIN MINE, REDDING, CALIFORNIA

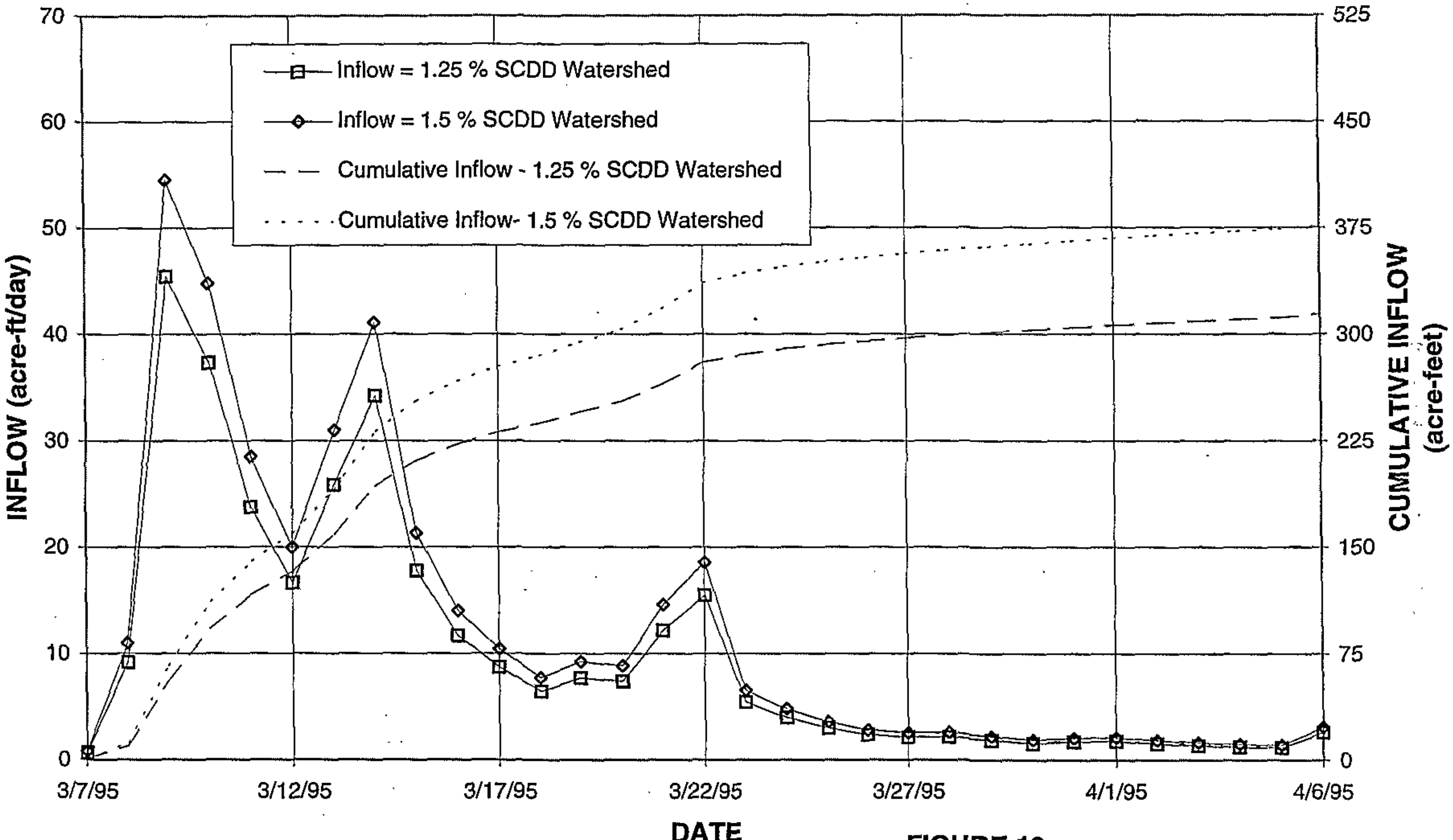

FIGURE 12
MARCH 1995 STORM
ESTIMATED SLICKROCK DAM INFLOW
SLICKROCK CREEK DAM SIZING EVALUATION
IRON MOUNTAIN MINE, REDDING, CALIFORNIA

Memorandum Reviewing SMI's Natural Background Document

Following is a memorandum prepared by D. Kirk Nordstrom and Charles N. Alpers of the U.S. Geological Survey (USGS), dated January 15, 1997. This memorandum presents a review of Shepherd Miller Incorporated's "Natural Background Document," entitled *Determination of Natural Background Metals Concentrations in Boulder and Slickrock Creeks, Iron Mountain Area, Shasta County, California.* That document was prepared by Shepherd Miller (SMI) for Stauffer Management Company on June 28, 1996.

Prepared for: Rick Sugarek, U.S. EPA, Region IX, San Francisco, CA

Prepared by: D. Kirk Nordstrom and Charles N. Alpers, USGS

Date: January 15, 1997

Subject: REVIEW OF NATURAL BACKGROUND DOCUMENT OF SMI - "Determination of natural background metals concentrations in Boulder and Slickrock Creeks, Iron Mountain Area, Shasta County, California," prepared for Stauffer Management Company by Shepherd Miller, Inc., June 28, 1996

Description and Major Findings of Document

This study reports 6 independent approaches to justify high concentrations of Cu and Zn (in the range of 0.25 - 5 mg L^{-1} and 0.13 - 2.2 mg L^{-1}, respectively) as representative of natural background in stream waters draining Iron Mountain before mining. The following 6 approaches were used to arrive at these concentrations:

(Section 2) summary of published literature values for acid drainage in unmineralized areas
(Section 3) Cu and Zn concentrations from seeps and wells in gossan outcrops
(Section 4) leaching experiments on Iron Mountain gossan and mineralized rock
(Section 5) statistical treatment of analytical data
(Section 6) conceptual hydrogeologic model
(Section 7) sulfide oxidation rates.

Section 8 of the report discusses the estimated natural background concentrations in the context of EPA water quality standards for aquatic life.

The report concludes that much of the Cu and Zn loads now observed in Slickrock and Boulder Creeks were present prior to mining and that this background will become an increasing part of the metal loads as the waste materials are continually washed by rainfall.

Response to Major Findings in Document

We find that SMI's interpretation of natural background metal concentrations is very difficult to justify because it is fraught with ambiguities, uncertain assumptions, misuse of data, poorly constrained models, and unwarranted conclusions. The most striking feature lacking from this report is the effect of hydrologic conditions that existed prior to mining compared to the current hydrology. Water quality based on seeps and ground waters that occur today under grossly different hydrologic conditions than what likely existed before

mining may make the current metal concentrations of those seeps irrelevant to the arguments presented. Another major problem is how to discern background concentrations in an area having an "overprint of many years of mining, milling, smelting, and construction (SMI, 1996, p. 5)." Finally, the conceptual models are not well-enough constrained nor realistic enough to provide a useful estimate of what natural background or pre-mining water quality conditions might have been.

We give our specific criticisms to each of the 6 approaches below:

Section 2. Survey of the published literature.

Findings of Section 2

Survey of the published literature on natural acid rock drainage. The basic contention in this approach is that the water quality at unmined mineralized areas can provide a natural analogue to what the water quality at sites like Iron Mountain might have been before mining. The main publication referred to is by Runnells et al. (1992) in which a review of more than 40 references from the literature shows that waters from unmined mineralized areas can have pH values as low as 2.6, copper concentrations as high as 68 mg L^{-1}, and zinc concentrations as high as 272 mg L^{-1}. Concentrations of Cu and Zn can also be less than 0.001 mg L^{-1} in waters draining mineralized areas. The highest concentration for zinc comes from water at the Red Dog Deposit, Alaska, which is admitted in the report to be unusually high compared to most waters in unmined mineralized areas. The next highest concentration (16 mg L^{-1}) is from a stream in the Northwest Territories, Canada. Runnells et al. (1992) also mention that the reported concentrations were highly variable and dependent on season. The conclusion is that reported metal concentrations in surface waters can be very high near metal deposits that have not been mined, therefore metal concentrations in surface waters at Iron Mountain where massive amounts of pyrite are exposed to weathering must have been high.

Response to Findings in Section 2

Concentrations of metals in waters draining unmined mineralized areas may have little analogy to Iron Mountain because geologic and hydrologic conditions are different.

For a comparison to be made between weathered, mineralized areas that have not been mined with pre-mining conditions in areas that have been mined, there must be some justifiable similarities in the climate, topography, geology, and hydrology (especially oxygen accessability) of the analogous sites. Metal loadings and concentrations in streams are a function of all of these factors, yet there is virtually no mention of them in the SMI report. Average annual loadings from the analogue locations cited by Runnells et al. (1992) were not provided either in the paper or in the SMI natural background report reviewed here. The Red Dog Deposit, containing the highest background concentrations of metals known for any unmined site, is a black siliceous shale containing high concentrations of fine-grained, highly-reactive metal sulfides with little to no carbonate-buffering capacity. This site occurs in Alaska in a very different climatic region from that of Iron Mountain. Hence, the geology and climate and, presumably, the hydrology are not comparable to Iron Mountain and do not justify a comparison for analogous purposes. The same could be said of most of the sites mentioned by Runnells et al. (1992). A site should be used that has similar geologic, hydrologic, and mineralogic characteristics.

Section 3. Cu and Zn concentrations from seeps and wells in gossan outcrops

Major Findings in Section 3

Collection and analysis of ground water and evaporative minerals from massive gossan at Iron Mountain. From 11 completed boreholes, 5 were converted to monitoring wells but 2 remained dry so that only 3 wells were accessible to ground-water sampling (SMI-01, SMI-10, and SMI-11). Well SMI-01 sampled the top 7.2 feet of the ground-water table, SMI-10 the top 24 feet, and SMI-11 the top 16 feet, although significant variability in the position of the ground-water table was noted. The drillholes encountered massive and disseminated gossan grading downward into less-oxidized and more mineralized rock (greater pyrite content) and rhyolite. Cavities and fissures were commonly encountered during drilling because of the considerable volume reduction that accompanies weathering of sulfides to gossan. Considerable structural and mineralogical heterogeneities characterize this part of Iron Mountain.

Monitoring of SMI-01 provided 7 discrete water samples between March 1995 and March 1996. The well is screened in weathered and mineralized rhyolite containing up to 20% sulfides. The pH values vary between 2.52 and 4.57 but only 2 samples were higher than 3.10. The dissolved Cu concentrations ranged from 21.8 to 49.2 mg L^{-1} and Zn concentrations ranged from 4.32 to 8.37 mg L^{-1} and are claimed (SMI, p. 9) to "clearly represent background levels for ground water in the gossan and demonstrate that natural weathering of the sulfide-bearing rocks at Iron Mountain produces low pH, metal-rich waters."

Monitoring of SMI-10 provided 5 discrete water samples between April 1995 and March 1996. The well is primarily screened in gossan containing less than 1% pyrite. The pH values were more consistent and slightly higher than those in SMI-01 (3.22 to 3.33). The Cu concentrations were an order of magnitude less than those at SMI-01 (1.44 to 2.71 mg L^{-1}) whereas the Zn concentrations were the same or slightly less (1.54 to 5.55 mg L^{-1}). No comment was made as to the representativeness of the SMI-10 concentrations relative to those found at SMI-01.

Monitoring of SMI-11 provided 4 discrete water samples between April 1995 and March 1996. The well is screened over the gossan/rhyolite contact but less than 1% pyrite was found in the drill cuttings. The pH values are circumneutral (6.61 to 7.39) and the Cu and Zn concentrations are all at or below 0.1 mg L^{-1}. This water was considered anomalous, not typical of gossan ground water, but was included in estimates of natural background because it came from the massive gossan.

Monitoring of Weston well E-1 was screened at 76 feet below the surface at the gossan/rhyolite contact but no information was given on depth to water table. Five water samples were collected between April 1995 and March 1996. Low pH values were found (2.37 to 2.62), Cu concentrations comparable to SMI-10 (0.602 to 3.35 mg L^{-1}), and Zn concentrations less than

SMI-10 but greater than those found at SMI-11 (0.266 to 0.726 mg L^{-1}). Higher pH and higher Cu and Zn concentrations were obtained by Weston in 1989 when the drillhole was first sampled.

A seep in a fault zone at the west end of the Brick Flat open pit was also reported as an example of natural ground water unaffected by mining. It was found to have a pH of 2.86, a Cu concentration of 6.77 mg L^{-1} and a Zn concentration of 19.7 mg L^{-1}. This and other seeps were sampled by Stauffer Chemical Company personnel in the 1970's that showed Cu concentrations in the range of 0.23 to 136 mg L^{-1} and Zn concentrations in the range of 0.35 and 515 mg L^{-1} but exact sampling conditions were not available. Nine samples of evaporative salts were collected from gossan outcrops and found to have Cu concentrations up to 0.29% and Zn concentrations up to 0.38%. The minerals kalinite, hexahydrite, gypsum, ferricopiapite, and rhomboclase were identified by X-ray diffraction. Such salts will produce acid solutions with soluble Cu and Zn when dissolved during rainstorms.

Response to Findings in Section 3

Assumptions that weathering conditions in the gossan today and metal concentrations in current gossan ground water are natural, for a site that has undergone extensive changes in hydrogeology, air permeability, and oxidizing conditions from underground and surface mining, are unwarranted.

Post-mining hydrology can affect the ground-water chemistry considerably, therefore post-mining ground-water samples cannot safely be assumed to represent "natural background." The main assumption in this section is that, even though there have been considerable changes in the hydrogeology due to mining, there are no consequent effects on the ground-water chemistry. This assumption is never made explicitly and it would be incorrect. One of the effects of mining is to increase the production of acid waters and the concentrations of metals by allowing oxygen to gain faster and more complete access to the sulfides. The construction of underground mine workings and an open pit will dramatically change the potentiometric surface, affecting the direction and velocity of ground-water flow, and it will deepen the transport of oxygen into the mineralized areas, thereby enhancing the oxidation rate of the sulfides and the amount of acid waters and the concentration of metals in them. Once the ground-water conditions and air permeability have changed, then seeps that are sampled during post-mining periods cannot be said to be unaffected by mining and labeled "natural background." For example, the seep at the west end of the open pit might not have been flowing in the direction of the present day pit if there had been a mountain instead of a pit at that location. It probably would have flowed in the opposite direction, consistent with the overall trend for topography and gravity to govern ground-water flow. The concentrations of Cu and Zn might have been lower due to anoxic conditions that may well have existed at that point in the flow system because it would have been under a 100 feet of rock and perhaps 10 to 50 feet of groundwater.

Four wells, all in close proximity, all near the top of the ground-water table, and all showing large variations in chemistry between each, cannot provide an adequate representation of pre-mining ground-water quality in gossan. The four wells and one seep that were presented as examples of ground-water quality in massive gossan are all in close proximity to each other and to the open pit. They all may be strongly influenced by the change in hydrology and the greater amount of air permeability caused by the existence of the open pit. Furthermore, the most acidic waters (SMI-01)with the highest metal concentrations were described as a clear representation of background levels for ground water in gossan. It is difficult to understand how a description like this can be justified without any reference to the hydrology, or why this location, and not the others with higher pH and lower metal concentrations (sometimes by orders of magnitude), is considered more representative. More samples over a wider area and away from the pit influence and described within the context of the hydrologic conditions might be able to represent gossan ground-water quality.

Statements referring to the "natural weathering of the gossan" (p. 11, section 3.6) are misleading. Weathering of gossan or other portions of a mineral deposit would be considered "natural" if the site has not been altered by human activities in any way that would have increased the rate of weathering and the rate of acid water production. However, mining activities clearly have the effect of increasing the weathering rate of sulfides by lowering the water table, introducing much greater quantities of air, and exposing sulfides by fracturing during blasting, drilling, and excavation. The current weathering rates and metal loading are therefore not indicative of natural background because the hydrogeology and air permeability are so markedly changed from their pre-mining conditions.

Section 4. Leaching experiments on Iron Mountain gossan and mineralized bedrock

Major Findings in Section 4

Leaching studies were done on three types of materials: (1) massive gossan derived from weathering of massive sulfide ore, (2) fractured rhyolite bedrock containing disseminated sulfides, and (3) disseminated gossan derived from weathering of disseminated sulfide in rhyolite bedrock.

Massive gossan samples were taken from drill cuttings (boreholes SMI-01, -02, -03, -04, -05, -06, and -08) in "shallow, intermediate, and deep portions of the gossan". Leaching experiments were run for both 24 hours and for 7 days in 3 inch diameter PVC about 15 inches long, using deionized water. Table 4-4 tabulates sample weights and water volumes used in the leaching experiments and indicates that the porosities used were 46-75%. Metal concentrations after the first 24 hours of leaching were generally higher than after 7 days. The difference was attributed to removal of the "most readily soluble materials (i.e. soluble salts) and enhanced rinsing in the initial 24-hour flush." The average copper concentrations for twelve 24-hour experiments was 43.6 mg L^{-1} and the average zinc concentration was 15.9 mg L^{-1}. For the 7-day experiments, the average copper concentration was 27.5 mg L^{-1} and the average zinc was 12 mg L^{-1}. The results were compared to the well water composition located nearest to the drill cuttings where possible.

Batch leaching experiments were conducted using drill core samples of fractured bedrock containing disseminated sulfides from the "bedrock transition zone." Four core holes were drilled in proximity to other existing monitoring wells. Five bedrock samples were selected for the batch leaching tests. Deionized water was combined with the uncrushed core samples in glass beakers and agitated for one week, leaving the rock fragments intact. Leachate chemistry for each core sample was compared to nearby wells with screened intervals at similar depths and found to be (p.19) "qualitatively consistent." Differences in Cu/Zn ratios in two of the experiments compared with nearby wells was attributed to (p. 20) "the highly variable compositions of the sulfate salts."

Disseminated gossan samples from surface outcrops and "an unoxidized siliceous bedrock sample from Capitol Waste Rock Pile (WR 10B)" were used for additional batch leaching experiments with deionized water. The samples were broken into 1-2 inch fragments. SMI contends that the increased surface area exposed as a result of breaking the samples was minimal compared to the total surface area of particles exposed to water within the sample. The methodology was otherwise similar to the core leaching experiments. Results for 6 of 7 gossan samples showed generally low leachate concentration of Cu (0.004-0.065 mg L^{-1}) and Zn (0.004-0.156 mg L^{-1}). SMI points out in Table 4-9 that the deionized blanks for these experiments also contained 0.004 mg L^{-1} of both Cu and Zn, so the lower values may indicate contamination. A seventh gossan sample and the mineralized bedrock gave more elevated concentrations of Cu (1.92 and 0.18 mg L^{-1}) and Zn (1.5 and 0.372 mg L^{-1}), respectively, at the end of the experiment. Based on these experiments, SMI concludes (p. 22) "... a minimal amount of metals appears to be released to water flowing over the completely oxidized materials at the surface of the disseminated gossan outcrops."

Average metal concentrations from leaching studies using sulfide-bearing bedrock (5 core samples in Table 4-6 and one outcrop sample in Table 4-9) are Cu, 19.9 mg L^{-1} and Zn, 4.66 mg L^{-1}. SMI uses these concentrations in section 6 to estimate background metal concentrations in Boulder and Slickrock Creeks.

Response to Findings in Section 4

The gossan and bedrock leaching experiments using drill cuttings, core, and outcrop samples were done in such a manner that it is not known how much of the solubilized Cu and Zn were actually leached in a manner comparable to natural pre-mining conditions and how much were artifacts of the procedure. Conclusions regarding natural leaching are not warranted from these experiments because of the increase of surface area and exposure of fresh sulfide surfaces to air from drilling and breakage.

Drilling to produce cuttings or cores, or breaking outcrop samples increases the sulfide oxidation rate artificially. Drilling breaks up the rock into fragments, increases the surface area, and exposes fresh sulfide surfaces to oxidation. This fracturing can greatly enhance the sulfide oxidation rate causing acid waters and high metal concentrations to occur in leach tests that may bear no relation to the "natural" leaching in the subsurface. The results do give some indication that the greater the sulfide content of the rock material, the greater the metal concentrations, and this result would be consistent with the idea that most of the leached metals came from sulfide surfaces freshly exposed during drilling and sampling.

Acidic pore waters associated with the drill cuttings will dry and form soluble salts on storage and contribute artificially elevated metal concentrations to the leach tests. The other problem with these leach tests is knowing the amount of acid water associated with the drill cuttings. SMI suggests that soluble sulfate salts may have contributed to the higher metal concentrations in the 24-hour leach test. These salts may well have formed from the drying out of residual acid water that accompanied the drill cuttings, i.e. acidic pore water. Such solubilized material would not bear any relation to metals "naturally" leachable from the gossan or bedrock, it would only indicate that the rock fragments were contaminated before the leaching experiment took place and would not be representative of natural weathering.

The use of unbroken core fragments in the bedrock leaching studies represents in an improvement over the use of drill cuttings, however, this method is also subject to significant artifacts. The outer surface of the core is freshly cut and likely to have exposed sulfide minerals that would not have been exposed to solutions percolating through natural fractures prior to drilling. Similarly, the use of outcrop samples that have been broken into 1-2 inch pieces could also have exposed fresh sulfide surfaces. Although the total surface area may not have been significantly increased by the drilling and sample preparation, the reactive surface area of sulfide minerals may have been significantly increased, increasing rates of sulfide oxidation and metal release during the experiments artificially. Therefore, the measured concentrations may have no bearing on the metal release rates in the undisturbed subsurface.

Increased surface area will affect the absolute final dissolved metal concentrations unless an equilibrium precipitation reaction that removes metals from solution is occurring or unless the reaction goes to completion. On p. 16, bottom paragraph, the 2nd sentence reads, "Increasing the surface area of the less-soluble materials increases the rate of metal release to solution, but does not affect the absolute final concentrations of dissolved constituents." This statement makes little sense without further explanation. Only two situations that we can think of would make this statement true: (1) a precipitation or adsorption reaction removing a metal from solution was occurring at a rate as fast or faster than the sulfide oxidation/dissolution reaction or (2) the reaction went to completion by exhausting the reactants so that the reaction path did not matter. Neither of these situations are likely to have occurred during the one week experiments, therefore, we conclude that increasing the surface area did indeed have a significant affect on the final concentration of dissolved constituents.

Section 5. Statistical treatment of analytical data.

Major Findings in Section 5

Principal Component Analysis (PCA) and Stepwise Discriminant Analysis (SDA) were used in an attempt to identify "families or classes of water that represent background metal concentrations for Boulder Creek and Slickrock Creek." Sixty-seven (67) samples from monitoring wells and seeps collected in the dry season (October to December, 1995) were used. Fourteen geochemical parameters were used in the analysis, including pH, Al, As, Ca, Cd, Cu, Fe, K, Mg, Mn, Na, Pb, sulfate, and Zn.

PCA/SDA analysis was used to group the samples into 11 groups. Groups A, B, and C contain wells SMI-01, -10, and -11, as well as several other samples. Some samples reside in more than one group. The presence of wells SMI-01, -10, and -11 in Groups A, B, and C were used to infer that these Groups represent "background" conditions.

An average Cu concentration of 5.7 mg L^{-1} and a Zn concentration of 8.5 mg L^{-1} were computed for 15 wells from within statistical Groups A, B, and C. Seven water samples (UND-01, HN-02, HN-04, HN-05, HN-06, and Seeps 10A and 10B) that were members of Groups A, B, and C, based on the statistical analysis, were excluded from the computation of the average concentrations because these well and seep waters "...in the Hornet area may be artificially affected by the Hornet Mine workings..."

Response to Major Findings in Section 5

The statistical analysis is not clearly defined, the results are not adequately discriminatory, misleading descriptions are used, and the number of samples is inadequate to warrant a conclusion regarding natural background levels of metal concentrations.

Use of the term "natural waters" is ambiguous and potentially misleading. On page 24, in paragraph 2, the report states, "Because waters from Wells SMI-01, SMI-10, and SMI-11 are known to represent natural waters within the massive gossan at Iron Mountain, the presence of these wells within a group is used an objective measure to classify groups of natural waters in the statistical analysis." SMC seems to be implying by the use of this term that the metal concentrations in these waters have not been influenced by human activities. This assertion is not consistent with what is known about the hydrologic perturbations to the system caused by mining and development activities, which have lowered the water table considerably, resulting in exposure of larger volumes of mineralized rocks and sulfide mineral surfaces to oxidizing conditions. The water chemistry in Wells SMI-01, SMI-10, and SMI-11 may have been affected by a declining water table in association with the excavation of the Brick Flat Pit, which would have exposed additional sulfide minerals to oxidation, resulting in higher metal concentrations than prior to mining.

The statistical functions and methodology are not defined. The values of the canonical discriminant functions that are used in the PCA/SDA analysis are plotted on Figure 5-1. However: 1) the functions themselves are not defined; 2) the methodology used for constructing the groups is not defined; and 3) no information is provided regarding the robustness of the statistical fit. Only the average values of the canonical functions for each Group are shown, so it is impossible to evaluate the basis on which the groups are discriminated.

Some statistical groups have only one, two, or three sample members and cannot be considered statistically meaningful. Groups A, B, and C, which are interpreted by SMI to represent "background" wells and seeps, each include 10 or more samples. In contrast, Groups E, F, H, and I each contain only a single sample, and Groups D, G, J, and K each contain only two or three samples. It is therefore not surprising that the smaller groups contain chemical outliers showing statistical differences from the larger groups. The basis for joining Groups A, B, and C into a "minimum statistical family" is not explained. Based on Figure 5-1, Groups F and D seem to be reasonably close to the values for Groups A, B, and C, but were not included. (This would have made little difference in the case of Group F, which consists only of sample HN-06, a sample site that was excluded from the "background" group on the basis of being possibly affected by the Hornet Mine workings (see next comment).

The method by which sites have been included for statistical treatment appears to be arbitrary. On page 25, paragraph 2: "Although the ground water in the area of the Hornet Portal has the same statistical signature as background Wells SMI-01 and SMI-10 the well and seep water (Wells HN-02, HN-03, HN-04, HN-05, HN-06, Seeps 10A and 10B) in the Hornet area may be artificially affected by the Hornet Mine workings, and were therefore not included in the calculations that determine the natural concentrations of copper and zinc for background Groups A, B, and C."

The fact that the chemistry of wells and seeps in proximity to the Hornet Mine workings has the same statistical signature as "background Wells" SMI-01 and -10 indicates a fundamental flaw in the use of statistical analysis as a method for distinguishing ground waters unaffected by mining from ground waters that are affected by mining. The statistical approach has not succeeded in distinguishing mined from unmined areas in the way that SMI has intended. However, it could be argued that most or all sampling sites in Groups A, B, and C have been affected by mining to some degree, and therefore cannot be distinguished statistically.

The components used for the statistical families has not been consistent and no explanation has been provided for the change. The present report does not refer to a statistical analysis presented by SMI in its report of September 14, 1995 ("Preliminary determination of background copper concentrations in Boulder and Slickrock Creeks, Iron Mountain Area, Shasta County, California", p. 13-15). In that analysis, four "families" of water (A, D, J, and M) were distinguished and "may represent natural background chemistry." Fluoride was noted as one of the main dissolved components distinguishing these "families" from other water samples. Therefore it is surprising that fluoride was not reported for the samples considered in the statistical analysis described in SMI's June 28, 1996 report.

Section 6. Natural metal loads from conceptual model.

Findings from Section 6.

Estimation of natural metal concentrations in Slickrock and Boulder Creek. In this section, background metal concentrations in Boulder and Slickrock Creeks are determined from a hydrogeochemical conceptual model that uses metal concentrations for ground waters derived from well water compositions, gossan and bedrock leaching experiments, and results from statistical analyses.

Six assumptions are inherent to the conceptual model:

1. The chemistry of ground water is well-maintained by rapid reaction between gossan, sulfides, and ground water. The reactions are assumed to be fast enough to be virtually instantaneous relative to the flow of ground water through the subsurface.

2. Infiltrating rainwater displaces ground water that subsequently discharges into the creeks.

3. The relative volumes of gossan ground water entering the watersheds are proportional to the areas of the gossan exposed in each watershed.

4. The displaced ground water below gossan outcrops are diluted by infiltrating rainwater, surface runoff, and shallow interflow during its transport to the creeks.

5. The volume of water per unit area that enters the watersheds are assumed the be the same on a unit area basis for each area of massive gossan, mineralized bedrock, and non-mineralized bedrock.

6. The area of disseminated gossan is used as a conservative estimate for the area of mineralized bedrock.

The model has been used to calculate metal concentrations in the creeks under conditions of winter high-flow and summer low-flow. The model for high-flow assumes that for every inch of rainfall, 1 inch of gossan ground water is displaced and is diluted with 1 inch of runoff water. A simple mass balance approach is used to calculate the final concentrations of Cu and Zn in the creeks. Three masses make up the total that ends up in the creeks: the "massive gossan ground water," the mineralized bedrock water, and the surface runoff water. The concentrations of Cu and Zn used in the model for "surface runoff water" were taken from slurry equilibration experiments using "non-mineralized surface material." This "non-waste landslide material" was collected from a transect on the Iron Mountain of Boulder Creek between waste rock piles WR-18 and WR-12. Average metal concentrations in the slurry experiments were found to be Cu, 0.025 mg L^{-1} and Zn, 0.067 mg L^{-1}. These concentrations were used for dilution flows from "surface runoff and non-mineralized bedrock." These three sources are mixed in proportions determined by their relative volumes (based on their areal coverage) and their metal concentrations.

Response to Findings in Section 6

The approach used in this section is not independent of the other approaches, it leads to results biased on the high side because of biases in the conceptual model and biases in the source data, and it is inconsistent in its use of mixing ratios.

Because the data in this section is based on results from 3 other sections, the approaches used to determine natural background metal concentrations cannot be "independent." The executive summary and the introduction both state that 6 independent approaches are being used to estimate natural background (pre-mining) concentrations in the creeks draining either side of Iron Mountain. The approach in section 6 depends upon data and conclusions in sections 3, 4, and 5. Hence this approach cannot be considered "independent." Furthermore, the approach described in this section is subject to the same criticisms made for sections 3, 4, and 5.

Model results give incorrect Cu/Zn ratios for Boulder Creek natural background conditions and an impossibly high Cu concentration and load for Boulder Creek during low-flow. All indications are that Cu/Zn ratios in Boulder Creek water should be <1.0 because Cu tends to be less abundant than Zn, Cu is more easily attenuated (adsorbed or precipitated) than Zn, and current Cu/Zn ratios are <1. The Cu/Zn ratio in the model results, however, are >1 because the main source (massive gossan water, and leach experiments) is >1. The wells from which gossan waters were taken are on the drainage of the Slickrock Creek side of Iron Mountain where the richest Cu ores were found and the highest known Cu/Zn abundance in the ore zone would be found. This accounts for the higher Cu/Zn ratios in Slickrock Creek but they are still only slightly greater than 1. The unusually Cu enriched waters from the wells in massive gossan would also help to explain the low-flow modeled concentration for Boulder Creek being 168% of the observed value, an impossible result. The Cu load and concentration is likely to be overestimated for both creeks for these reasons. The 168% load value is a strong indication that the model itself is not appropriate for the use for which it was intended.

The use of surface material from the landslide area between WR-12 and WR-18 as representative of "non-mineralized bedrock" throughout both Boulder and Slickrock Creek watersheds is inappropriate. No descriptions or chemical analyses of these materials are provided. It is likely that these materials contain metal concentrations in excess of the average values for soils and truly unmineralized bedrock elsewhere in these watersheds. A better proxy for runoff from unmineralized areas would be the composition of Boulder and Slickrock Creeks above the influence of mining at Iron Mountain. Although there are outcrops of disseminated gossan in the upper parts of these watersheds, the Cu and Zn concentrations are generally lower than those used by SMI in their calculations.

The fact that the observed Cu and Zn concentrations for both creeks during summer or winter are well within those values reported by surveys in the American and Russian literature is meaningless. The values for Cu and Zn concentrations in waters draining unmined mineral deposits from the American and Russian literature covers 3 to 5 orders of magnitude. This range is so huge that more than 90% of all analyzed waters probably fall within the range. Hence, this statement does not provide a useful constraint or confirmation of what natural background at Iron Mountain must have been.

The assumption of constant proportions of massive gossan water to disseminated gossan (or mineralized) ground water to surface runoff during winter high-flow seems highly unlikely and results seem unreasonably biased towards high concentrations and loads. The mechanics of ground water to surface water contributions for winter high-flow conditions are such that (1) the proportions should not remain exactly constant at 1:1:1 but, instead, will vary with seasonal and storm context and history, (2) there should be a tendency for a contribution from dilute ground water to increase during the winter season and no allowance has been made for this effect, and (3) contributions of water from non-mineralized areas were included for low-flow conditions but inexplicably absent from high-flow conditions. These considerations would lead to lower concentrations and loads than those produced in the SMI model.

Section 7. Copper and zinc fluxes from oxidation rates.

Findings from Section 7

Calculation of copper and zinc fluxes to ground water from published oxidation rates. This calculation uses a published number for the oxidation rate of pyrite from Nicholson and Scharer (1994; incorrectly cited in the text as 1992) along with several estimates and assumptions to find the fluxes of Cu and Zn from rock to the ground water. The basic assumptions used in the calculation are:

1) the average thickness of the oxidized zone is 1 meter
2) the average amount of sulfide in the oxidized zone is 60%
3) the average density of rock in the oxidized zone is 275 lbs ft-3
4) the average surface area can be estimated from the particle size (~1.5 mm)
5) the average copper content is 3% of the ore
6) the average zinc content is 3.5% of the ore

The results indicate that 8,030 lbs/yr of Cu and 9,855 lbs/yr of Zn should be released to ground water in the Boulder Creek watershed and 44,900 lbs/yr of Cu and 54,000 lbs/yr of Zn should be released to the Slickrock Creek watershed. These numbers are said to compare favorably with the observed Cu and Zn fluxes between March 1995 and February 1996 of 39,800 lbs/yr and 29,500 lbs/yr for Slickrock Creek and 11,500 lbs/yr and 23,800 lbs/yr for Boulder Creek.

Response to Findings on Section 7

The conceptual model presented by SMI appears to represent copper and zinc fluxes based on published sulfide oxidation rates. Our analysis indicates that it is not a useful model because it grossly oversimplifies the actual processes known to occur and the parameters, when adjusted to be more realistic, bear no resemblance to known field data on metal loading rates. A model that contains such a huge sensitivity to uncertainties in both the input data and the possible processes cannot provide a useful constraint on the natural-background loading of metals to the watersheds.

The assumptions made for these calculations are incomplete and faulty, and some of the citations are incorrect. The assumptions are incomplete for two reasons. One of the assumptions implicitly made is that the sources of Cu and Zn oxidize at the same rate as pyrite. The source of Cu is the mineral chalcopyrite and the source of Zn is the mineral sphalerite. Chalcopyrite oxidizes about 28 times slower than pyrite and sphalerite oxidizes about 4 times slower than pyrite (Rimstidt et al., 1994). Another implicit assumption is that once the sulfide minerals have oxidized, there are no processes that will attenuate the dissolved metals. It is highly likely that processes of sorption, precipitation-dissolution, oxidation-reduction, dilution, diffusion, and dispersion will have some effect on the consequent metal loadings into the drainages. The other assumptions are discussed below:

1) "the average thickness of the zone of oxidation is 1 meter." This assumption is not justified. It is not stated why 1 meter was chosen so it must have been an arbitrary assumption for the purposes of the calculation A better estimate of the zone of oxidation would be the variation in ground-water table because this would be the most active zone of oxygen transport to fresh sulfide surfaces. In figure 3-9 on page 3-18 of the Roy F. Weston Report (1991) the ground water level varies over 20-30 feet (6-9 meters). Greater fluctuations are always experienced near and at the top of the ground-water divide where it is most sensitive to changes in recharge. Ground-water table fluctuations of several meters are not unusual (Davis and De Wiest, 1966; Meinzer, 1942). Hence the zone of oxidation could be 5-10 times greater than that estimated by SMI at the top of the water table and decreasing to about a meter or less at the sides. Overall, the average thickness might be more reasonably estimated at 1 to 3 meters.

2) "the average amount of sulfide in the transition zone is 60 percent of the total rock." The average amount of sulfide in the transition zone depends on what the definition of the transition zone is. The transition zone will, undoubtedly, vary in sulfide content with vertical distance and with time. It is probably not so important what the actual sulfide content is, but rather how sensitive are the results to changes in this parameter. The results are not likely to be too sensitive but they can be checked.

3) "the density of sulfide minerals in the transition zone is equal to the average density of massive sulfide ore (275 lbs/ft^3) at Iron Mountain." The given density converts to 4.4 g ml^{-1}. Pure pyrite would have a density of 5.0 g ml^{-1} but the density of massive sulfide ore would be less than this because chalcopyrite, sphalerite, silica, and other gangue minerals will have densities closer to 4.0 g ml^{-1} or less and the occurrence of porosity will decrease the overall density of the massive sulfide. Hence, the value of 275 lbs/ft3 is very reasonable.

4) "the surface area of the sulfide particles in the transition zone corresponds to particles with an average diameter of 1.5 mm (estimated from visual inspection of sulfide lenses within gossan)." According to Kinkel et al. (1956) the pyrite grain size is typically in the range of 0.1 to 2 mm, with most of the particles in the 0.1-0.4 mm size range. Hence, 0.25 mm would be a better estimate of the average grain size, especially for the more reactive particles. A further problem arises with the application of a regressed equation for the surface area as a function of particle size based on Parks (1990). The equation in this report is log(A) = 0.415 - log(diameter in cm.). Parks (1990) does not provide the parameters for his linear equations but examination of the fitted lines in his paper indicates that this equation represents the pure geometric surface area/particle size relationship and not the empirical relationship that Parks (1990) found for quartz grains. The parameters for this equation are from Nicholson (1994; incorrectly cited as Nicholson and Scharer, 1992; there is a paper by Nicholson and Scharer, 1994 similar to the given citation but this does not contain the information cited). Nicholson (1994) also gives an equation for geometric pyrite (cubes or spheres) but this equation was not used by SMI. If we

assume that the lower of the 2 fitted lines by Parks (1990) for crushed and screened quartz grains is appropriate for sulfides and use an average particle size of 0.25 mm, then a better estimate of the surface area would be about 167 cm2 g^{-1}. The main problem with these surface area estimates is that the whole mass of estimated pyrite and its related surfaces are not exposed to air and water. It is the "reactive surface area," subject to water contact, that matters. This property cannot be measured. Estimates of reactive surface area for simple solids indicates that it can be a small fraction of the total measured surface area. Reactive surfaces that are exposed to air and water flow will be a still smaller fraction. Whether the estimates given here are useful can be indicated by comparing with present fluxes and by performing a sensitivity analysis. Only the former was done in this report.

5) "copper comprises approximately 3.0 percent of the ore (Kinkel et al., 1956)." Based on data in Kinkel et al. (1956), this statement is correct.

6) "zinc comprises approximately 3.5 percent of the ore (Kinkel et al., 1956)." Based on data in Kinkel et al. (1956), this statement is correct.

The first step in the calculation is to find the number of moles of pyrite per cubic meter of ore. The value given is 36,740 mol m^{-3} and is found to be correct.

The next step is to calculate the surface area per mole of pyrite. We estimate that the value of 0.208 m2 mol^{-1} is probably too low by about an order of magnitude.

The third step is to multiply the two previous values to get the surface area of pyrite per cubic meter of ore. Again, this would be too low by an order of magnitude because of the error in the surface area, resulting in a value of 73,600 m^2 m^{-3} instead of the reported value of 7,600 m^2 m^{-3}.

The fourth step is to multiply the previous number by the pyrite oxidation rate to get the rate of pyrite oxidized per cubic meter of ore. The pyrite oxidation rate of 5×10^{-10} mol m^{-2} s^{-1} cited in the SMI report is from Nicholson (1994; incorrectly cited as Nicholson and Scharer, 1992). However, it only applies to a pH of about 2.0, a temperature of about 25/C, and oxygen as the oxidant. The oxidant that directly attacks pyrite is known to be ferric iron at low pH. Ferric iron oxidizes pyrite about two orders of magnitude faster than oxygen. A review by Nordstrom and Alpers (1996, unpublished data) indicates that independent studies on pyrite oxidation by ferric iron are in good agreement with a rate of about 1×10^{-8} mol m^{-2} s^{-1}. Using the oxidation rate with oxygen as the oxidant and the incorrectly stated surface area, SMI reported a reaction rate per cubic meter of ore as 3.82×10^{-6} mol s^{-1} m^{-3}. If we use the surface area value of 73,600 m^2 m^{-3} then the reaction rate would be 36.8×10^{-6} mol s^{-1} m^{-3}. If we use a pyrite oxidation rate based on ferric iron then the reaction rate would be 0.74×10^{-3} mol s^{-1} m^{-3} or a rate that is more than two orders of magnitude faster than that calculated by SMI.

The fifth step takes 3% of the reaction rate for the number of moles of copper released, i.e. 1.15×10^{-7} mol s^{-1} m^{-3}. Based on our analysis, the rate for copper would be 2.2×10^{-5} mol s^{-1} m^{-3}. The conversion to pounds of copper released per day per cubic meter of ore gives the value reported in SMI of 1.39×10^{-3} lb(Cu) d^{-1} m^{-3}. Using our estimates, the rate would be 266×10^{-3}

lb(Cu) d^{-1} m^{-3}. If we include the fact that chalcopyrite oxidizes 28 times slower than pyrite then the rate would be 9.5×10^{-3} lb(Cu) d^{-1} m^{-3}.

The final step involves converting the copper release rate into metal loadings per day for the two respective watersheds, Slickrock and Boulder. The area of weathering gossan in Boulder Creek watershed is given as 2.87×10^{5} ft^{2} and the depth is 1 meter of which only 60% consists of sulfide. This estimate gives 22 lb(Cu) d^{-1} in the SMI report compared to 4210 lb(Cu) d^{-1} from our estimates, or 150 lb(Cu) d^{-1} if the chalcopyrite oxidation rate is used.

In the discussion of the results, the copper load calculated for Boulder Creek is compared to the measured load on an annual basis. The theoretical calculation from SMI gives 8,030 lb yr^{-1} compared to 1995-96 empirical data that gives 11,500 lb yr^{-1}. Our estimates, however, give 1,540,000 lb yr^{-1} based on more realistic estimates of the parameters used. Alternatively, if the chalcopyrite oxidation rate is used, the loading is 55,000 lb yr^{-1}. These values are clearly gross overestimates and we use them to point out that seemingly reasonable parameters can be manipulated to provide an apparently reasonable result (as in the case of SMI's results) simply because it compares well with field observations. Unfortunately, a good comparison with field data is a necessary but insufficient criterion for a useful conceptual model. There are numerous models that compare well with observation but are poor or useless models; likewise, there are useful models that do not compare well with observation. For a conceptual model to be useful it must also be based on the best available data, the best information on processes, and it must be logical. We have shown that the SMI model is not based on the best available data. When better data is used, the results are meaningless. We now consider inadequacies in the conceptual model that would lead to the gross overestimates we obtained with the better input parameters.

The main problem with the conceptual model is that all the estimated sulfide is assumed to be reacting instantaneously at the given rate and instantaneously transported to the creek. In other words, hydrologic residence times or transport and mixing rates, hydrologic flow paths, and chemical attenuation rates play no significant role in the loading of metals to the creek. We disagree with these implicit assumptions. Some of the water that picks up reaction products from oxidizing sulfides probably ends up being diverted into the mine workings and gets transported to the neutralization plant. The subsurface water also has a finite residence time during which copper released on oxidation of chalcopyrite can be reprecipitated to form secondary sulfides that are known to occur at Iron Mountain or adsorbed onto iron oxyhydroxides. These processes would greatly slow down the movement of copper from the oxidizing zone to the surface water. Another problem is that the rate of sulfide oxidation may be dependent on the transport rate of oxygen to the subsurface. This rate has not been given any consideration in the calculations. There are also complicating factors such as gradients in temperature, pH, and solution composition, fluctuating water tables, and heterogeneous fracture flow that could affect loading rates significantly.

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Review of Determination of Natural Background Metals Concentrations in Boulder and Slickrock Creeks, Iron Mountain Area, Shasta County, California

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Description of Document

This document, *Determination of Natural Background Metals Concentrations in Boulder and Slickrock Creeks, Iron Mountain Area, Shasta County, California* (Shepherd Miller, Inc. [SMI], June 28, 1996 [SMC Vol. 63, Tab 7]), contains SMI's preliminary estimates of pre-mining background concentrations of metals. The document contains the following sections:

1.0 Introduction

2.0 A survey of the worldwide literature that summarizes copper and zinc concentrations in surface water associated with unmined ore deposits similar to massive sulfide ore deposits at Iron Mountain

3.0 Groundwater and salts associated with gossan

4.0 Leaching studies of massive gossan, disseminated gossan, and mineralized bedrock materials

5.0 Statistical analysis of selected groundwater analyses

6.0 Estimation of natural metal concentrations in Slickrock Creek and Boulder Creek

7.0 Calculation of copper and zinc fluxes to groundwater from published sulfide oxidation rate

8.0 Toxicity estimates for natural concentrations

9.0 Summary

SMI concludes that much of the copper and zinc loads now observed in Boulder and Slickrock Creeks are of natural origin and were present prior to mining activities.

Summary Response to Findings in Document

As discussed in more detail below, SMI has greatly overestimated the pre-mining background concentrations of metals in Boulder and Slickrock Creeks. Whereas SMI's stated intent is to determine the pre-mining background concentrations, the methodology employed by SMI to calculate pre-mining conditions is more indicative of the post-mining condition.

The report culminates in SMI's prediction of pre-mining metal concentrations based upon a straightforward model developed by SMI. As explained below, the key inputs to the model (such as the metal concentrations associated with gossan, disseminated gossan, mineralized bedrock, and water from unmineralized areas) reflect the elevated metal concentrations associated with areas perturbed by mining and related activities, rather than metal concentrations associated with mineralization in its natural, undisturbed condition. The SMI model is overly simplistic. For example, the model ignores the hydrogeochemical processes that permitted the weathered gossan and secondarily enriched portion of the mineralization to form and that prevented the primary and secondary mineralization from being completely weathered. The model also ignores the hydrochemical processes in a natural, undisturbed system that limit the flow of metal-rich waters and permit relatively unobstructed flow of cleaner water. As a result of these errors and others discussed below, the model *greatly overpredicts the amount of metal that would have been present in Slickrock and* Boulder Creeks in the absence of mining.

The problems with the SMI model are confirmed in separate approaches by evaluations of the performance of the SMI model against known field conditions. First, when the SMI model is tested using a mineralized area at Iron Mountain that is relatively undisturbed by mining activity, the SMI model overpredicts the metal concentrations by a factor of about 500 for copper and about 48 for zinc. Second, one could evaluate the reasonableness of the SMI estimate by calculating the amount of gossan that would have been generated by that metal flux rate and comparing that value with the amount of gossan at Iron Mountain and the amount that could reasonably have been removed by erosion. These two simple comparisons reveal that SMI has grossly overestimated metal concentrations associated with the natural, undisturbed conditions at Iron Mountain.

Finally, the pre-mining concentrations estimated by SMI are inconsistent with the biological investigations conducted by EPA which indicate that the current chemical barrier that exists in Spring Creek has existed for only a relatively short period of time (i.e., the period since mining began at Iron Mountain). These independent factors support the conclusion that the SMI estimate is a gross overstatement of the true pre-mining metal regime at Iron Mountain.

Major Findings or Major Review Comments in Document and Responses

Findings in Section 1.0 (Introduction)

a. This section contains a background discussion regarding the physical and chemical processes of gossan formation at Iron Mountain and the associated impact on water chemistry. SMI does not discuss the ways in which mining changed or affected these processes.

b. SMI states that the determination of pre-mining background concentrations of metals in waters of mineralized districts such as Iron Mountain is difficult because of the overprint of many years of mining, milling, smelting, and construction. Therefore, SMI uses six "independent" approaches to estimate the background copper and zinc concentrations of Boulder Creek (BC) and Slickrock Creek (SC). These methods include:

  - A survey of the worldwide literature that summarizes copper and zinc concentrations in surface water associated with unmined mineralized areas (Section 2.0)

- An evaluation of groundwater and salts associated with gossan (Section 3.0)
- An evaluation of leaching studies of massive gossan and disseminated gossan (Section 4.0)
- An evaluation of leaching studies of mineralized bedrock materials (Section 4.0)
- A statistical analysis of selected groundwater analyses (Section 5.0)
- Calculation of copper and zinc fluxes to groundwater from published sulfide oxidation rates (Section 7.0)

Response to Findings in Section 1.0

a. The report describes the processes that created the mineralization at Iron Mountain. Because the report is intended to distinguish the effects of mining from the pre-mining condition, it would have been helpful to provide a description of the ways in which mining affected the hydrology and geochemistry at the site. Such a discussion would aid the reader in evaluating, among other things, the SMI claims that the well sampling locations have not been impacted by mining, whether SMI has adequately distinguished between the rate of oxidation attributable to undisturbed and unimpacted mineralization versus mineralization that has been disturbed or otherwise impacted by mining, and whether the model adequately accounts for the significant changes in hydrology that occurred at the site as a result of mining.

b. Although the report purports to contain several approaches to calculating "natural background," the way in which SMI implements each approach tends to significantly overestimate the contribution of pre-mining, undisturbed mineralization. One significant limitation with the SMI work is the very limited basis for estimating the values of key variables used by SMI. For example, SMI relies on four sampling locations to develop its estimate for "natural" metal concentrations in groundwater. However, the sampling locations are in an area impacted by mining (see the Response SMC96-3 in the technical memorandum responding to the *SMC Response to Public Comment IMM Water Management FS Addendum,* from SMC, dated July 1, 1996, and the technical memorandum re *Review of Appendix O to Rhone-Poulenc, Inc.'s Reply Memorandum re Natural Background Levels)* and in close proximity to each other, so the groundwater data are not representative of sitewide pre-mining conditions. Similarly, SMI relies on leach tests to establish the potential for gossan to release metals to Slickrock and Boulder Creeks. These leach tests are indicative of mining impacts, not pre-mining metal concentrations, because these leach tests measure the extent to which freshly exposed areas of gossan leach metals. In an undisturbed condition, the exposed portion (or reactive surface area) of the gossan would be much more fully oxidized and would result in both a higher pH and lower release lower metal loads. Subsequent tests conducted by SMI on weathered gossan confirm that leachate from fully weathered gossan is comparable to water from non-mineralized zones. EPA investigation of an area of relatively undisturbed gossan similarly indicates that undisturbed gossan does not release appreciable metal or acidity. See the technical memorandum re *Evaluation of the SMI Methodology for Estimating "Natural Copper and Zinc Concentrations" Applied to the Catfish Pond Area, Iron Mountain Mine.*

The report does not adequately evaluate the ways in which mining has changed the geology and hydrology at Iron Mountain. The report assumes that, because weathering processes and the sulfide minerals are natural, all metal releases associated with weathering are not caused by mining. However, this oversimplification ignores the dramatic difference between weathering of undisturbed gossan and gossan disturbed, crushed, drilled, and partially excavated by mining. Because SMI ignored one of the most significant ways in which mining has affected the site, it is not surprising that the SMI has greatly overestimated the releases attributable to pre-mining conditions. The SMI report also ignores changes in hydrology caused by mining, such as changes in groundwater table elevation and in the direction of groundwater flow. For example, the SMI "background" gossan sampling locations are right next to a large mining pit; prior to mining, the wells would have been next to a large hill. The excavation of this large area lowered the groundwater table, exposing previously unoxidized sulfide minerals to post-mining oxidation. One SMI "background well" is located at a point that, until as recently as 1994, was beneath a sulfide-rich mine waste pile; the well itself is underlain by mine workings. The extremely elevated metal concentrations in this well are clearly impacts of mining activity.

SMI's report does not take into account processes that limit the transportation of metal. Other work conducted by SMI at Iron Mountain has indicated that only about half of the copper released at the surface is transported by rainwater. See the technical memorandum responding to *Chemistry, Mineralogy, and Potential Metal Loading of Surface Salts*, by Shepherd Miller, Inc., dated October 27, 1995. The residual portion of the copper is retained in gossan through adsorption by iron oxides and oxyhydroxides and also through the local formation of the secondary copper sulfide minerals, such as chalcocite. This latter process, known as secondary (or supergene) enrichment, increases the grade of copper sulfide deposits and in some cases makes them into minable ores. This natural attenuation of copper in groundwater would be more pronounced than that of surface conditions because of the greater amount of water-rock interactions along groundwater flow paths and the greater likelihood of attaining sufficiently reducing conditions. Failing to account for these reactions and failing to simulate realistic conditions causes SMI to overpredict the results of the leaching and groundwater tests.

Finally, although SMI characterizes the six approaches taken in its report as independent, some of the approaches are in fact inter-dependent. For example, the statistical analysis in Section 5 uses chemical data for groundwater from monitoring wells in gossan, that are also used as a basis for the analysis in Section 3.

Findings in Section 2.0 (Literature Survey)

In this section, SMI summarizes a literature survey of water quality from mineralized areas worldwide. Based on this literature survey, SMI estimates that the pre-mining copper and zinc concentrations in Boulder and Slickrock Creeks ranged from <0.001 to 68 mg/L for copper and <0.001 to 16 mg/L for zinc. SMI believes that the highest published value for zinc of 272 mg/L in stream water near the Red Dog deposit in Alaska provides a reasonable basis for estimating the pre-mining metal concentrations at Iron Mountain, but to be conservative, SMI does not use this figure in its estimate. SMI instead estimates pre-mining discharges using the next highest value of 16 mg/L for zinc, which is the concentration measured in a stream in the Northwest Territories, Canada. Although not stated in the text in Section 2, SMI uses the highest copper concentration (68 mg/L) from the same area as an indicator of pre-mining copper levels in Boulder and Slickrock Creeks, based on the inclusion of this value in Table 6-4.

Response to Findings in Section 2.0

There are several fundamental problems with the approach used by SMI in this section. First, the estimated ranges cited by SMI for copper and zinc concentrations are so great (spanning more than five orders of magnitude) that the ranges are of little use in developing a meaningful estimate of pre-mining metal concentrations. The fact that other SMI estimates are consistent with this range is of little meaning because the range is so large.

Second, this entire section is based upon a study published by Donald D. Runnells, Ph.D (SMI). Recent deposition testimony by this author raises serious questions about the reliability of the claims that the data in the report reflect metal releases from unimpacted mining areas. In particular, that testimony indicates that:

1. The author believes that drill holes would not affect the representativeness of the water quality data from the well in an otherwise undisturbed mineralized area as depicting "natural background" conditions, and similarly, that cutting a road into or performing exploratory activities in an otherwise undisturbed mineralized area would not affect the representativeness of the water quality data from that area as depicting "natural background" conditions.

2. The author had not personally inspected the areas that he reported to be unimpacted by mining activity (even though his primary source of data was from a mining exploration journal).

3. The author did personally inspect/identify a seep emerging from a roadway cut into the sidewall of an open pit mine and claimed the seep to be unimpacted by mining activity.

The author's testimony that these activities, which would expose fresh sulfides to oxidation and increase metal releases, would not impact water quality is not supported by sound scientific reasoning. This testimony, coupled with the author's identification of areas of Iron Mountain that have clearly been impacted by extensive mining activities as "natural background," raises serious questions regarding the validity of the study relied on by SMI and referenced in this section of the SMI report.

Third, the SMI analysis is overly simplistic and fails to discuss and analyze factors that are necessary to make the type of comparison SMI is attempting to make. For example, SMI suggests that pre-mining metal concentrations at Iron Mountain would have been similar to those found in the waterway with the second highest natural metal concentrations reported in the world (16 mg/L zinc and 68 mg/L copper). SMI concludes that its approach is "conservative" because SMI excludes the waterway with the highest level of naturally occurring metals. Despite SMI's reliance upon this waterway, SMI provides no flow information for the supposedly analogous waterway, so it is not known if the other waterway is a seep of a few gallons per minute or a creek or stream of the magnitude of Boulder or Slickrock Creeks.

The SMI analysis ignores or inadequately addresses other important factors as well. As discussed in the technical memorandum reviewing Section 14(d) of the *Preliminary Evaluation of the Geochemistry of Potential Sources of Metal Loadings to Boulder Creek, Iron Mountain*

California (SMI, June 1995), there is significant variability between mineral deposits that make this type of analysis highly speculative and unreliable.

Each ore deposit has many geologic factors that influence the environmental effects: deposit size, host rocks, surrounding geologic terrain, wall rock alteration, nature of the ore, ore mineralogy and chemistry, gangue mineralogy and ore/gangue mineralogical and chemical zonation, grain size, secondary mineralogy, topography, hydrology, and, importantly, the mining and milling methods. The environmental signatures include climate; soil and sediment mineralogy and chemistry (soil types, thicknesses, and distribution) prior to mining; surface water and groundwater chemistry impacted from metals mobilized from mine wastes, mill wastes, and smelter wastes; and changes in groundwater regime resulting from dewatering, underground workings, pits, ponds, etc., imposed on the regional groundwater system.

The difficulty in finding a sufficiently similar ore deposit to that of Iron Mountain is apparent by considering even the difference between water compositions and metals concentrations in Boulder Creek and Slickrock Creek at Iron Mountain. These two creeks are separated only by a ridge, but the two streams have significantly different water characteristics, including the copper-to-zinc ratio. See the technical memorandum responding to *Copper to Zinc Ratios in Boulder Creek and their Applicability to Identifying Potential Source Materials*, by Shepherd Miller, Inc., dated September 14, 1995.

To be considered appropriately similar for purposes of developing a meaningful estimate of pre-mining metal concentrations, a wealth of information is needed in addition to the water concentrations reported in a surface water in the vicinity of the mine. SMI does not even discuss the characteristics of the receiving waters associated with the discharges, such as flow, seasonal variability, and temperature.

A review of the document underlying the SMI "conservative" estimate indicates the general lack of rigor in SMI's scientific approach and the general absence of supporting documentation for conclusions reached in the analysis. For example, certain data presented by SMI from cited references do not indicate whether the samples are filtered or unfiltered, and the field laboratory analytical results have unknown accuracy and precision. This lack of scientific rigor on the data reporting makes the metals concentrations reported by these references to be of unknown quality, useful for information, but data that should not be used as a basis for estimating background metal concentrations even in the area that was being investigated. SMI concludes that a deposit in Ontario, Canada, provides evidence of the pre-mining metal concentrations at Iron Mountain. For this proposition, SMI relies upon a single citation in Runnells, et al., 1992 - Cameron, 1978.

First, the Cameron paper is primarily written to document the use of lake waters for base metal production, so the paper does not provide any meaningful analysis or documentation of whether an area is in fact truly unimpacted by prior mining or exploratory activity.

Second, the bulk of the Cameron article focuses on characterizing the metals concentrations in the lakes; the article contains very little information about the characteristics of the sampled stream area or the sampling methods. The data upon which SMI relies are found in a single sentence: "Two stream waters flowing from the 'A-B' zone into the lake measured 1800 ppb Zn, 1000 ppb Cu at pH 3.8 AMD 16,000 ppb Zn, 68,000 ppb Cu at pH 3.0." Cameron p.229. The article does not provide any information to permit an evaluation of the sampling effort, including sampling location, sampling date(s), sampling methods, or stream flow characteristics on the sampling date and at other times. The author does not attempt to explain the dramatic range in the measured metal concentrations. SMI did not even discuss the manner in which these two dramatically different waters could be relied on to produce a representative characterization of the site discharge in its analysis. Cameron states that water samples were analyzed on "50 ml of unacidified and <u>unfiltered</u> water samples," suggesting that the samples were unfiltered. The sample may have contained an unknown but potentially major amount of iron oxyhydroxides that had adsorbed the copper, and to a lesser extent the zinc, reported in the analysis. Because it was not reported, we do not know how these samples were collected and the observed characteristics of the flow for each sample. The sample may have contained a high proportion of bed sediment disturbed by the sampling effort.

Third, the information that Cameron does provide indicates that the area is quite different than Iron Mountain. Cameron states that the area is characterized by poor drainage; the drainage is sparse and intermittent. Cameron notes that the seeps and springs occur in the summer when thawed channels occur in the permafrost. Since the area is under permafrost conditions, the seeps and springs would not commence to flow until some time after the snow has begun melting and the ground is beginning to thaw. Even during the summer, permanently flowing streams in the area are sparse. Cameron also notes that as the seep flow increases, the metal concentrations decrease: "Seep waters may be rich in base metals... during the remainder of the summer these seeps decline in volume but tend to increase in metal concentration."

These conditions are in sharp contrast to the swift and continuous (perennial) drainage from the steep topography at Iron Mountain. The different flow regimes are in part attributable to the climatic differences between the two areas. Iron Mountain is located in an area that is almost never subject to freezing. In contrast, the Canadian deposit and stream bed "all lie within a zone of permanent permafrost." Permafrost conditions exacerbate the metals concentrations released because oxidation products are released during a shorter period of time, usually in lower volumes of water. Both of these factors would increase metal concentrations but not necessarily increase the load of metals being released. The colder temperatures present in Ontario would also increase the solubility of oxygen in water. This greater oxygen availability could potentially increase the rate of oxidation relative to undisturbed conditions at Iron Mountain by increasing the amount of oxygen available for sulfide oxidation.

The Cameron article also indicates that the grade of ore present at the Ontario site is quite different than the grade at Iron Mountain. The article reports that this area in Canada contains 3.5 percent copper and 2.5 percent zinc. These metal deposits are in sharp contrast to the lower grades of ore at Iron Mountain, which typically contains an average concentrations in the range of 1.1 percent copper and 1.3 percent zinc. The lower grade ore would be expected to release lower concentrations of metals (other factors being equal).

Another important factor is the amount and speciation of the ore mineralogy exposed or within sufficient depths to be oxidized. For example, at Iron Mountain, Kinkel, et al., 1956, indicate that oxidation of the massive sulfides depends on the orientation of the deposit. A horizontal or nearly horizontal massive sulfide remains unoxidized if it is overlain by host rocks between 100 and 150 feet thick, but a nearly vertical orientation can have localized oxidation occurring up to depths of 500 feet. These depths may decrease for the northern colder climates with permafrost, but may increase in tropical environments. It is important to consider these variables when trying to understand the amount of massive sulfide undergoing active oxidation. SMI does not consider or discuss these important factors in its analysis.

SMI also does not evaluate other important differences in deposit type. For example, the U.S. Geological Survey (USGS) has published a study that evaluates ore deposit types, *Preliminary Compilation of Descriptive Geoenvironmental Mineral Deposit Models*, edited by E.A. du Bray, USGS Open-File Report 95-831 (1995), 272p. In this publication, both the Iron Mountain ore deposits and the ore deposits at Kidd Creek, Ontario, are classified as a Kuroko-type of "Volcanic-Associated Massive Sulfide Deposits." SMI considers the Red Dog deposit to be similar to the Iron Mountain deposit, but the USGS report classifies that deposit as a "Sedimentary Exhalative Zn-Pb-Ag Deposit," a completely different type from the one found at Iron Mountain with different expected water chemistry. Several of the other "natural background" areas cited by Runnells, et al. (1992), in Appendix A to the SMI report represent a third type of massive sulfide deposit recognized by USGS, as the "Mississippi Valley-Type Pb-Zn Deposit," which is hosted by carbonate rocks.

Because of these uncertainties and the large variability in factors, this approach lends itself to great uncertainty, particularly where important differences in deposit characteristics are not adequately considered. The highly simplistic analysis conducted by SMI, which essentially involved listing the range of metals found in waters flowing through mineralized areas worldwide, does not provide a reliable indicator of the pre-mining conditions at Iron Mountain, or a reasonable "check" on the other approaches employed by SMI in this report.

Findings in Section 3.0 (Groundwater and Salts Associated with Gossan)

In this section, SMI analyzes water collected from monitoring wells (SMI-01, SMI-10, SMI-11 and E-1) within the gossan rock outcrops and unconsolidated materials, as well as water quality in a seep in Brick Flat Pit (BGSeep1).

a. SMI concludes that the metal concentrations in SMI-01 clearly represent background levels for groundwater in gossan and demonstrate that natural weathering of the sulfide-bearing rocks at Iron Mountain produces low-pH, metal-rich waters. Dissolved copper and zinc concentrations in this well range from 21.5 to 49.2 mg/L (copper) and 4.86 to 8.37 mg/L (zinc).

   SMI uses data from SMI-01 and three other wells to determine the range of copper and zinc concentrations in groundwater. The other three wells used by SMI included SMI-10 (copper 1.44 to 2.71 mg/L and zinc 1.54 to 5.55 mg/L); SMI-11 (copper <0.003 to 0.013 mg/L and zinc <0.002 to 0.107 mg/L) and Well E-1 (copper 0.602 to 3.35 mg/L and zinc 0.402 to 0.726 mg/L). SMI uses the average value from these four wells (9.5 mg/L copper and 2.3 mg/L zinc) for its modeling efforts.

b. SMI believes that the role of gossan in providing acidity and metals to groundwater and surface runoff at Iron Mountain is demonstrated by water from a seep in a fault zone in Brick Flat Pit, BGSeep1. SMI concludes that the seep is unaffected by mining or disposal of sludge in Brick Flat Pit.

c. SMI also discusses the process by which acidic "natural" waters within gossan rock outcrops are concentrated by evaporation during the dry season and form discontinuous crusts of metal-sulfate salts (especially on residual sulfides), which dissolve in rainstorms, releasing significant amounts of acidity and metals to surface waters at Iron Mountain.

Response to Findings in Section 3.0

a. SMI contends that these sampling locations (SMI-01, SMI-10, SMI-11, and E-1) indicate the metal concentration in groundwater in gossan undisturbed by mining activities, but this contention is almost certainly wrong. It is highly likely the wells are strongly influenced by the change in hydrology and the greater amount of oxygen permeability caused by the existence of the open pit and the presence of extensive underground workings in the vicinity of the wells.

   The four wells are all in close proximity to the large, open pit mine. Wells SMI-01 and E-1 are drilled into an area that is underlain by extensive mine workings that have altered the groundwater table in the area. Well SMI-01 was also drilled into an area that until 1994 was the site of a pyritic waste pile. Open pit mining at Brick Flat Pit exposed the ore body by removing the overlying bedrock, increasing the rate of oxidation by several orders of magnitude. Mining in the area involved blasting, excavating, and the removal of millions of tons of material. These activities not only exposed new areas to free-flowing air and water, but also caused fractures that permitted the introduction of air and water to sulfide material that previously would have been in a reduced (i.e., no free oxygen) environment. This mining activity changed the water table in this area, which would also have increased the rate of oxidation in these wells. For example, prior to mining, the wells would have been located next to a large hill. Now, as a result of mining, the wells are located next to and above a large pit. The open pit and the extensive workings in this area beneath several of the wells have greatly altered the water table and flow paths of groundwater in the area.

   Changes to the groundwater table are evidenced by the several dry wells constructed by SMI. Of the five wells completed by SMI, only three have water. Were SMI truly sampling in an undisturbed portion of the water table, it is unlikely that the wells would have been dry, especially in intervals with preserved sulfide mineralization. (The preserved sulfide mineralization indicates that these areas were previously below the groundwater table. Otherwise, the sulfides would have become oxidized over geologic time).

   Even though water was found in three of the SMI wells, it is not possible to know precisely where this water came from and whether the flow path or water quality was affected by mining. Understanding where the water came from is important because the water could reflect mining-related impacts if it has passed through an area affected by mining or because mining could have enabled the water and free oxygen to travel to the location where it is found. For example, surface runoff or infiltration of contaminated surface water could have carried contaminated water to the sampling location. Also, fractures caused by mining would have facilitated the transportation of water and oxygen to freshly exposed sulfides.

   The groundwater sampling results also overstate the metal concentrations that would be present in undisturbed gossan because the act of sampling groundwater itself is likely to have disturbed the pre-mining condition. In addition, if water was removed from the monitoring wells at a rate faster than the natural recharge, then additional sulfide minerals would have been exposed to the atmosphere, thereby accelerating the processes of sulfide mineral oxidation and metal release to solution. These reactions are rapid enough that significant changes in water quality could result over the course of hours. This type of disturbance could have increased the concentration of metals in the water samples above the concentrations that would have been present in the undisturbed gossan.

It is also unlikely that the wells are representative of pre-mining sitewide conditions because the wells are in such close proximity to each other, so the wells would not be representative of site-wide conditions. In addition, even though the wells are in close proximity to each other, the wells show large variations in chemistry between each well. This disparity suggests that there is a large degree of variability in water quality of the area, and that a much larger number of monitoring points would be necessary to adequately characterize present conditions, or that significant uncertainty is involved in any attempt to use these four wells to represent background conditions.

Another problem is that the wells are all located near the top of the groundwater table. One would expect the highest concentrations of copper and zinc at the top of the groundwater table, as this would generally be the most oxidizing environment. With increasing depth at an undisturbed location, more reducing conditions are likely to prevail, leading potentially to the attenuation of copper by reaction with other sulfide minerals and formation of secondary copper sulfides such as chalcocite and covellite. The reduction of sulfate to sulfide is also a possibility at depth, which would lead to additional fixation of divalent metals such as copper and cadmium (and to a lesser extent, zinc and iron).

SMI develops its estimate of "background" by simply averaging four sampling locations. At a minimum, SMI should have rejected the data from SMI-01. That well is located in very close proximity to mine workings and is in a location that was used for several decades to store sulfide-rich mine wastes. These factors strongly indicate that the well is influenced by mining. The data from SMI-01 are an order of magnitude higher than the other values. Excluding that data point decreases the average copper concentration from 9.5 to 1.3 mg/L and the average zinc concentration from 2.3 to 1.2 mg/L. For the reasons discussed above, even this approach likely overstates by one or two orders of magnitude the pre-mining metal concentrations of groundwater in undisturbed mineralization.

b. SMI relies on sampling from a seep in a fault zone in Brick Flat Pit (the location of intensive open pit mining) to estimate pre-mining water quality of gossan. The location of the seep in close proximity to Brick Flat Pit makes it clear that the location has been impacted by mining. The area was only recently exposed to oxygen and water, thus evidencing a mine-related impact. Prior to mining, the location that is now the seep was beneath more than one hundred feet of rock. Mining also clearly altered groundwater flow and groundwater elevation in the area, changing the exposure of sulfides to oxygen and water. This seep is therefore an inappropriate location to use for estimating water quality in undisturbed gossan mineralization.

Open pit mining operations at Brick Flat Pit involved the removal of massive amounts of overburden and excavation of sulfide mineralization. Removal of the overburden and excavation of the mineralization exposed the fault zone (the seep) and allowed considerably more oxygen and water to flow into the fault and the mineralization in area of the fault that had previously been protected. This exposure greatly increased the oxidation and metal concentrations in the water. Exposing the fault also heightens the degree of evaporation occurring in the vicinity of the seep, which increases the metal concentrations contained in the water through the creation of metal rich salts.

Prior to the mining of the Brick Flat Pit, the location that is now the seep in question was beneath more than one hundred feet of rock. Therefore, even assuming that this fracture existed prior to mining, the water flowing at this point prior to mining would have been groundwater flowing through fractures in the rock with much less exposure to the atmosphere. Since mining exposed the seep to greater flows of oxygen and water, the metal concentrations in the seep represent mining-related impacts and not pre-mining conditions.

The chemical characteristics of the seep also suggest that the seep has been only recently exposed, which in turn strongly suggests that the seep is a mining-related source. A seep located in undisturbed gossan (i.e., gossan not disturbed by mining) would generally not contain water exposed to sulfides. A gossan is the iron oxide created by the oxidation of the sulfide. Within the millions of years since the mineralization was formed, the sulfides along a fault would have been oxidized to iron oxide along with the other sulfides that had been converted to iron oxide. While the gossan may include pockets of sulfides within at least a partially protected rim of varying iron oxide thickness, sulfides in fault zones are generally converted to iron oxide much more readily than unfractured massive sulfide.

In contrast to a typical seep in undisturbed gossan, this seep contains water associated with sulfide as shown by the chemical characteristics of the water in the seep. The seep also exhibits a dramatic range in copper and zinc concentrations (copper from 0.23 to 136 mg/L and zinc from 0.35 to 515 mg/L). The most likely cause of this dramatic range is evaporative metal-rich salts. These salts would be present in a typical seep in undisturbed gossan. The presence of the salts and other reaction products of sulfide in this seep strongly suggest that the seep has been exposed recently. The cause of that recent exposure is almost certainly the open pit mining that occurred in this area.

c. It is agreed that salts are a potential source of acidity and metals to Boulder and Slickrock Creeks. However, this fact does not indicate whether those salts are attributable to pre-mining conditions or mining-related impacts. Mining activity exposed previously protected sulfides to free oxygen and water, greatly accelerating the oxidation of the mineral and the production of salts. Thus, salts are not attributable solely to pre-mining conditions. Indeed, most if not virtually all of the salts are likely attributable to mining. The mine workings are the largest repository of exposed sulfides that generate the salts. As explained elsewhere, mining dramatically increased the exposed surface area of sulfide minerals, which in turn greatly increases the production of sulfide salts.

In considering the contribution of sulfide salts, one must also take into account the factors that control the transport of metals contained in the salts. For example, the rainfall simulation test on evaporative metal-bearing salts (SMI's technical memorandum *re Salt Chemistry and Mineralogy* [September 14, 1995]) demonstrated that only half of the copper in surface salts is transported by rainfall. The other half of the copper is believed to be retained by iron and aluminum oxyhydroxides. Therefore, if salt sources are to be considered, their effective copper concentrations should be decreased by 50 percent.

In summary, the groundwater investigation conducted by SMI does not accurately depict pre-mining conditions. Because the groundwater wells and the seep are impacted by mining, the sampling data from those locations represent mining impacts rather than pre-mining conditions. The investigation also fails to account for the manner in which mining changed the hydrology of the site. With respect to sulfide salts, it is agreed that sulfide salts are a source of metals, but because mining has increased exposure of sulfides to oxygen and water (which in turn permits the creation of large amounts of sulfide salts), the metal load attributable to salts should be considered a mining-related impact.

Findings in Section 4.0 (Leaching Studies)

In this section, SMI uses laboratory leach tests to estimate background copper and zinc concentrations in Boulder and Slickrock Creeks.

a. SMI used four criteria to select gossan for leaching:

   1. The selected cuttings did not come in contact with drilling fluid during collection.
   2. Cuttings were selected to cover shallow, intermediate and deep portions of the gossan.
   3. All samples were collected from above the water table.
   4. All samples were collected upgradient from any known or suspected mining operations.

   SMI contends that this leaching approach ensured that the metal concentrations would be similar to those leached from naturally occurring areas of massive gossan and, therefore, would be representative of the copper and zinc concentrations in pre-mining gossan water.

b. According to SMI, drill cores show a several-foot-thick section of fractured and weathered bedrock between overlying colluvium and unweathered rhyolite containing fresh sulfides. This zone of the drill core has permeabilities of greater than 0.01 cm/sec. SMI concludes from this information that the zone is capable of transmitting significant amounts of groundwater containing metals concentrations from the oxidation of the disseminated sulfides.

c. SMI compares the leachate from the laboratory tests with the groundwater from monitoring wells completed at the same depth interval of the samples. SMI concludes that the pH of the leachates is within one pH unit of the pH of the groundwater and that the quantity of the metals in the leachate is qualitatively consistent with the occurrence of metals in groundwater, although at different absolute concentrations.

d. SMI conducted leach tests on five samples of disseminated gossan samples. For these leach tests, SMI uses a water-to-rock ratio of 0.5 on four of the five samples. On the fifth sample, which is from the upper slide area, SMI uses a ratio of 0.6 (wt:wt). According to these experiments, a minimal amount of metals appears to be released from disseminated gossan outcrops. SMI concludes, however, that the areas mapped as disseminated gossan also have fresh sulfides at depth. SMI therefore assumes that disseminated gossan are a potential source of metals.

e. SMI averages the leachate test results and uses those average values in its model to estimate natural background concentrations of copper and zinc in Slickrock and Boulder Creeks. The values used by SMI are as follows:

   Gossan leaching studies: copper = 27.5 mg/L; zinc = 12.5 mg/L
   Sulfide-bearing bedrock: copper = 19.9 mg/L; zinc = 4.66 mg/L

f. SMI concludes that a significant portion of the groundwater at Iron Mountain is derived from "natural sources" because of (1) the abundance of massive and disseminated gossan at the surface of Iron Mountain and evidence of acidic metals-bearing water within gossan outcrops, (2) evidence of flow of water and gaseous oxygen causing active oxidation of sulfide minerals within gossan and fractured mineralized bedrock, and (3) the strong relationship between the occurrence of metals in leach experiments and water quality in corresponding monitoring wells.

Response to Findings in Section 4.0

In this section, SMI estimates background copper and zinc concentrations in Boulder and Slickrock Creeks using laboratory leaching studies of gossan and rhyolite bedrock. As discussed below, the leach tests significantly overstate the leachable copper concentrations and are more indicative of mining-relating impacts than natural, pre-mining conditions. The estimated metal concentrations in groundwater developed by SMI are at least an order of magnitude too high.

a. SMI relies on the leach test results from this section in its modeling efforts. Using leach tests rather than relying on data from actual groundwater data is highly questionable, particularly where the leach tests use fresh drill cuttings and cores and the tests rely on highly variable water-to-rock ratios in the leaching process. In this case, SMI uses fresh drill cuttings and relies on highly variable water-to-rock ratios.

   Using fresh drill cuttings is known to greatly overstate in-field leaching rates and is more indicative of mining-relating impacts than natural, pre-mining conditions (White, A. F., 1996).

   The drill cuttings do not represent the contact mineralogy between infiltrating water and gossan under natural conditions. The drill cuttings include particles of fresh sulfides and probably some of their secondary minerals, which are normally within and at least partially protected from oxidation by a rim of iron oxides and perhaps also encapsulated in silica. This rim of iron oxides and/or silica will become wet with the infiltrating water, but under natural conditions, infiltrating water moves relatively rapidly through major conduits to the groundwater system at and near the gossan/massive sulfide and/or gossan/rhyolite contact. Given the steep topography of this terrain and the normal difference between vertical and horizontal permeabilities, infiltrating water will tend to move laterally along the steep topography to the creek rather than to the gossan/massive sulfide and/or gossan/rhyolite contact. In these major conduits, the pyrite is already heavily oxidized, so only minor oxidation and metal releases will occur.

In contrast to this natural, pre-mining condition, the leach tests expose fresh, fine-grained sulfides and the outer part of the core to variable amounts of oxygenated deionized water to gossan-drill-cuttings ratios for 24 hours or 7 days, depending on test duration. The intact cores area is not a good indicator of pre-mining conditions because sulfide may be exposed by the drilling action on the outer part of the core. Fresh, fine-grained particles indicate mining impacts because these materials are generally not exposed in natural, undisturbed conditions.

Another problem with the leach tests is that they do not take into account the fact that the actual amount of oxygen remaining at the groundwater interface (the area where oxidation occurs in a natural, undisturbed system) with the sulfides may be much lower than the amount of oxygen in the leaching columns used for the leach tests, particularly where the interface exists at depth below the surface. In a natural, undisturbed system, oxidation occurs primarily at the groundwater interface, which, in an undisturbed condition, typically ranges from a few inches to a few feet thick. The groundwater interface is a zone that is alternately saturated and unsaturated as the water table fluctuates. However, even in that area, free oxygen flux is limited by rates of advection of air and water, the solubility of dissolved oxygen in water, and rates of oxygen diffusion through air and water. In the leachate experiments, however, the amount of oxygen is not limited in the same way by these factors because of differences in scale.

SMI acknowledges that the leach results during the initial 24-hour test were likely increased above natural conditions due to factors related to drilling and recovery of the core. It is commonly acknowledged that the initial leach test water contains suspended particulates and colloidal materials generated by the drilling process. However, SMI concludes that these factors would not affect the absolute final concentrations of dissolved constituents in the one-week tests. This conclusion is in error because it is highly probable that microbial activity will strongly enhance the oxidation of freshly exposed sulfide minerals and the growth of this microbial population will take a few days to two weeks to become established. The population will likely become well established, but not fully established, during the one week test.

SMI also fails to consider groundwater chemistry in its analysis. This failure causes SMI to overestimate pre-mining metal concentrations by a significant amount. The metal concentrations detected in the leach tests do not reflect the changes that would occur as the water is transported through conduits containing iron and aluminum oxyhydroxides. The exact amount of metal attenuation that would occur because of sorption or other processes is difficult to estimate, but it could be substantial (i.e., several orders of magnitude) depending on pH, available oxyhydroxide surface areas, and other factors.

In summary, the leachate experiments do not realistically represent the leaching of undisturbed, in-place mineralization. Even compared to the elevated groundwater levels measured in the wells from the disturbed mining area, the leaching drill cuttings overestimate the leachable copper concentration by more than an order-of-magnitude. This analysis suggests that the results from leaching drill cuttings are more typical of oxidation of sulfides in broken or fractured mineral wastes that result from the extensive mining activity at IMM rather than oxidation of undisturbed gossan. The results from the leaching experiments also fail to account for the loss of mobilized copper resulting from adsorption/precipitation, which would reduce copper concentrations by at least an additional 50 percent (based upon studies conducted by SMI).

b. SMI appears to base its position on visual observations, but defining permeability in this manner is neither reliable nor rigorous. Permeability is likely enhanced in the vicinity of the active oxidation because the acid generated by the oxidation process will dissolve some of the adjacent rock. The lateral continuity of mineralization is of considerable importance in determining the significance of groundwater flow through this zone. Permeability is a physical characteristic that can be defined by physical measurements - pump tests, grain-size distribution, etc. Visual estimates are subjective and can have orders of magnitude errors. The formation and release of acid will make the rock appear very porous but it may not be permeable. Water may not be able to move through the rock unless there is continuity in the porous rock that allows the water to move laterally through the geologic system.

c. SMI compares the bedrock leachate test results with water quality in nearby monitoring wells and concludes that the two compare favorably. However, a more careful analysis indicates that the comparison does not confirm the validity of leachate test results. First, the similarity of pH alone does not confirm the validity of the leachate test results. Second, SMI understates the chemical disparity between the bedrock leachate test results and the groundwater samples with regard to the absolute concentrations of copper and zinc. Third, SMI fails to evaluate TDS differences between the leachate and field data, as well as other compositional differences between the leachate and field data.

It is not surprising that the pH of the leachate mimics the pH of the sulfide mineralization because SMI uses an unbuffered deionized water as a leaching solution. Unbuffered deionized water would readily adopt the pH of the oxidation of even traces amounts of mineralization. The pH in a leach test would likely be between about 2 and 4 if there were only an extremely small amount of sulfide present in the bedrock fragments.

SMI also compares the bedrock leachate test results with water quality data from monitoring wells with respect to metal concentrations. SMI concludes that the results are "qualitatively consistent" but have "different absolute concentrations." SMI's characterization understates in important respects the problems between leachates and the groundwater from the same depth interval. First, the total dissolved solids (TDS) of the groundwater, the total amount of dissolved material from sulfides and their host rocks, is a factor of two higher than the leachate TDS (average 2,160 mg/L determined for groundwater and 924 mg/L TDS for average leachate). This substantial difference indicates that the leachate test results do not represent field conditions. There are also disparities between the copper and zinc values. Compared to the leachate results, the average copper concentration in groundwater is about 30 percent lower. Zinc concentration in the leachates is three times higher than in the groundwater. These inconsistencies show that the leachate test results are not representative of field conditions. While SMI concludes that the leachate tests are reliable indicators of field conditions, the conclusion is not correct. This analysis indicates just the opposite–that the leachate data are not reliable indicators of field conditions.

d. The average copper and zinc concentrations from the leaching of "disseminated gossan" are 0.021 and 0.036 mg/L, respectively (Table 4-8). This is a minimal amount of dissolved metals when the other leachates are considered. While the leachate tests results likely overstate the contribution of disseminated gossan, the values calculated by SMI are so negligible that the error is not likely to affect the analysis in a meaningful way.

e. While the leachate data suggest that disseminated gossan is not a meaningful source of metals to Boulder or Slickrock Creeks, SMI nonetheless considers disseminated gossan to be an indicator of "natural" metals. SMI assumes that unoxidized sulfides exist below all disseminated gossan areas. However, the extrapolation between surficial oxidized disseminated gossan to depth introduces additional uncertainty into its analysis. Many mining companies have learned that the depth of mineralization beneath an outcrop is often limited, in some cases even to the outcrop itself. In addition, unless there is some geological evidence that the rhyolite extends to some known depth beneath the oxidized outcrop, there is little likelihood that there are fresh sulfides at depth. In this case, SMI has provided no reliable evidence of rhyolite at depth below the disseminated gossan. While sulfides exist at depth in the heavily mined area, that fact does establish that unoxidized sulfides exist at depth in other locations. Since SMI has not provided evidence of fresh sulfides beneath the oxidized "disseminated gossan," SMI's extrapolation of mineralization to depth seems to be pure speculation. Even if such sulfides existed, SMI has not established that those sulfides are oxidizing to any appreciable degree. As explained elsewhere, in an undisturbed condition, the sulfides would have been protected from rapid oxidation by the lack of oxygen and water (otherwise the sulfides would have been oxidized). To the extent oxidation is occurring, the oxidation would be limited to a relatively narrow vertical interface zone where water flow may be limited to recharge to the zone.

   Mineralization is generally not a laterally extensive phenomenon. Although disseminated sulfide mineralization can extend some distance from the massive sulfide mineralization, the metal content of the disseminated gossan will decrease significantly (exponentially) as a function of distance from the massive sulfide. As the sulfide content decreases, so does the metal content, first copper and then zinc and cadmium. With greater distance, the sulfide becomes primarily just an iron sulfide, which can create a lower pH groundwater by oxidation but contains little to no copper or zinc.

f. SMI concludes that a significant portion of the groundwater at Iron Mountain is derived from "natural sources" because there is

   1. An abundance of massive and disseminated gossan at the surface of Iron Mountain and evidence of acidic metals-bearing water within gossan outcrops

Response: The gossan is highly weathered because it has oxidized for thousands if not tens of thousands of years. The water sampled by SMI is either low in metals or impacted by mining activities. SMI itself has submitted test data that indicate that highly weathered gossan does not contribute significant amounts of metal to groundwater.

2. Evidence of flow of water and gaseous oxygen causing active oxidation of sulfide minerals within gossan and fractured mineralized bedrock

    Response: Over geologic time, areas exposed to air and oxygen would have become fully oxidized. Mining has exposed new areas of mineralization, which exposes fresh pyrite and sulfides. These newly exposed areas are likely responsible for practically all of the oxidation that is currently occurring at the site. EPA's analysis of the water quality of groundwater and surface water in the Catfish Pond area indicates that relatively undisturbed, intact, highly weathered mineralization does not contribute significant metal discharges.

3. A strong relationship between the occurrence of metals in leach experiments and water quality in corresponding monitoring wells

    Response: As explained above, there is not a "strong relationship" between the occurrence of metals in leach experiments and water quality in corresponding monitoring wells.

Findings in Section 5.0 (Statistical Analysis)

In this section, SMI uses two specialized statistical analyses (principal component analysis [PCA] and Stepwise Discriminate Analysis [SDA]) to distinguish "natural background chemistry" from mining-related chemistry. These statistical methods are used to identify and classify populations of chemical data that show similarities and/or differences.

a. The underlying premise of the SMI statistical analysis is that water from Wells SMI-01, SMI-10, and SMI-11 represent "natural waters within the massive gossan at Iron Mountain." This conclusion is based upon SMI's observation that the "wells were completed in the gossan cap removed from any mine workings or waste rock piles."

b. SMI concludes that statistical analysis of the dissolved components in waters from wells suggests that the data from Groups A, B, and C should be combined into one family.

    SMI concludes that, because this family includes SMI-01, SMI-10, and SMI-11, the family "most clearly represent[s] background water derived from natural chemical weathering processes."

c. Groups A, B and C also include (1) monitoring wells and seeps within the landslide area in the Boulder Creek watershed; and (2) monitoring wells, seeps, and pooled water from the Hornet Portal area. According to SMI, some of these well locations "are in areas that are affected by mining"; therefore, some are excluded from the list of wells and seeps "identified as background" in Table 5-3.

d. According to SMI, "the statistical signatures of the 67 groundwater samples collected during the dry season indicate that the majority of dissolved components in waters within the landslide along Boulder Creek have a natural source. These natural waters result from the weathering and oxidation of sulfide deposits that are present within the rocks of Iron Mountain."

e. SMI excludes 7 of the 22 wells in Groups A, B, and C from its analysis because those wells are located in areas affected by mining. The chemicals analysis of waters from 15 remaining wells within the statistical Groups A, B, and C have an average copper and zinc concentration of 5.7 mg/L and 8.5 mg/L, respectively. These are the values SMI uses in its modeling.

f. According to SMI, on the basis of geologic and hydrologic factors, many more wells at Iron Mountain may also contain water of natural background origin; however, the 22 wells identified in the "statistical analysis" are grouped together purely on the basis of a statistical analysis of chemistry, and thus represent a minimal subset of probable background wells.

Response to Findings in Section 5.0

The SMI statistical analysis should be ignored. While SMI states that the statistical analysis distinguishes "natural background concentrations" from mining-related concentrations, the analysis in fact appears to determine that all metal concentrations in the waters considered result from mining-related activities. SMI's entire analysis hinges upon its assumption that Wells SMI-01, SMI-10, and SMI-11 represent "background" conditions, but as discussed above, this assumption is seriously flawed. There are also other problems with the analysis: the data set is too small, the data are strongly skewed, and the data are improperly treated. SMI also fails to provide the basis for using this highly selective data set.

a. The SMI statistical analysis depends upon SMI's assumption that Wells SMI-01, SMI-10, and SMI-11 represent "natural waters within the massive gossan at Iron Mountain." As explained above, post-mining hydrology can affect the groundwater chemistry considerably, so post-mining groundwater samples cannot safely be assumed to represent "natural background." With respect to the wells used in this analysis as "background," the evidence is particularly strong that the wells are impacted by mining. All of the wells are located in a heavily mined area. Some wells are located directly over or adjacent to mine workings that are known to be repositories of highly concentrated and highly acidic mine waters. All of the wells are located in areas that have been excavated by mining. The wells are in an area where the water table has been changed by mining. See Response to Findings 3 a, above. Because of this faulty SMI premise, the entire analysis is of no use.

b. Another key problem with the SMI analysis is the problem with the database and how the database was handled.

   First, the data set is too small. The three data sets that represent "background," Groups A, B, and C, each include ten or more samples. All of the other groups contain either one sample (Groups E, F, H, and I), or two or three samples (Groups D, G, J, and K). The fact that there are so few sampling points in these other groups explains why the groups contain chemical outliers that are statistically different from the majority of data points.

   Second, SMI does not properly treat the duplicate analysis. The "objective" way to statistically handle this database is to average the duplicates and then average the samples from two sampling events to compare single copper and zinc concentrations with the locations sampled only once. For example, there were a total of 67 analyses, but only 51 "wells, piezometer (1), and seeps (2 labeled as such)." Similarly, if NN-01 is the same as Noname-01, there are actually 21 discrete locations and 35 analyses listed on Table 5-3. This indicates that there are three sets of duplicates, 12 locations that were sampled twice, and 9 wells that were sampled once. The mistreatment of duplicates could also affect the grouping analysis. If additional sampling points were available, it would have been useful to evaluate the groupings for each sampling date. However, the data set is too small for the analysis to be useful.

Third, SMI uses only one mini-piezometer analysis and does not explain why SMI ignores all of the other mini-piezometer data. If one data point is used, all data points should be used, unless a compelling reason exists for excluding the other data.

SMI concludes that Groups A, B, and C represent "natural background." The SMI conclusion is not adequately supported, and the available evidence indicates that the conclusion is incorrect.

First, SMI does not adequately explain the basis for joining these three groups.

Second, these three groups represent 39 of the 51 sampling locations, or about 76 percent of the analytical data. It is highly unlikely that such a large group of sampling locations would represent background, when the sampling occurred in an area heavily impacted by mining. For example, most of the locations are associated with areas of most intense mineralization (e.g., the Hornet portal is listed as part of Group B in Table 5-1), which are the areas that are also most likely to have been mined. In fact, SMI acknowledges that the samples from the Hornet Mine area "are in areas that are affected by mining"; therefore, some are excluded from the list of wells and seeps "identified as background" in Table 5-3.

Third, an inspection of the analytical data not included in the set of "natural background" samples indicates that the discriminating function most likely excludes unimpacted wells and includes impacted wells. For example, SMI excludes two sample groups from "natural background" which have copper concentrations of 0.01 and 0.04 mg/L copper, respectively (Table 5-2), and 3.24 and 0.13 mg/L zinc, respectively. These values are substantially below the concentrations detected in wells considered "background" by SMI. Since natural background samples in a mineralized area are expected to be lower than mining-impacted samples from the same area, the exclusion of these data points suggests the discriminant function actually separated areas disturbed by mining rather than "natural background." SMI fails to explain the basis for the groupings.

Similarly, SMI concludes that 7 of the 22 wells in Groups A, B, and C are in areas impacted by mining. The fact that such a large percentage of the wells included in the "natural background" family indicates a fundamental flaw in the use of statistical analysis as a method for distinguishing groundwaters unaffected by mining from groundwaters that are affected by mining. Instead, the analysis likely groups together mining-related metal releases.

c. As explained above in Subpart b, whether a sample is a member of Group A, B, or C does not provide a reliable indication regarding whether the point represents a metal concentration associated with mining-related activities.

d. As explained above in Subpart b, the statistical signatures are not a meaningful indicator of whether a water sample represents a metal concentration associated with mining-related activities.

   In addition, SMI's conclusion that "the natural weathering of gossan" is the source of the metal in the "background water" is misleading. The source is unquestionably the sulfide mineralization in Iron Mountain. The important question in estimating pre-mining concentrations is, however, what is the amount of copper and zinc that this mineralization would have contributed to both creeks if mining had not occurred. As explained in Response 3 b above, mining has greatly affected the rate of weathering at Iron Mountain by exposing fresh sulfides and mineralization to free oxygen and water. Thus, the conclusion that the weathering is the source of metals does not provide any insight into whether the release is mining-related.

   The SMI statement is also problematic because it is unsubstantiated. SMI does not adequately distinguish between releases associated with weathering of undisturbed mineralization, weathering of disturbed mineralization, infiltration of water to freshly exposed mineralization, mine portal water, and water associated with waste piles and other mine waste, among other things.

e. As explained in Subpart b above, the fact that at least 7 of the 22 wells in Groups A, B, and C are impacted by mining strongly indicates that the statistical analysis is not functioning properly. This is particularly true when one realizes that several of the excluded locations have lower concentrations than those included and when one realizes that many of the excluded groups contain only a few members.

   For purposes of its modeling analysis, SMI uses the average copper and zinc concentrations from the remaining 15 wells in Groups A, B, and C (average copper and zinc concentration of 5.7 mg/L and 8.5 mg/L, respectively). Because the statistical analysis is flawed, these data should not be used.

f. According to SMI, on the basis of geologic and hydrologic factors, many more wells at Iron Mountain may also contain water of natural background origin; however, the 22 wells identified in the "statistical analysis" are grouped together purely on the basis of a statistical analysis of chemistry, and thus represent a minimal subset of probable background wells. As explained above, the statistical analysis is flawed, and the group of data points identified by SMI do not represent "probable background wells." The generalization by SMI regarding other wells is pure speculation.

Findings in Section 6.0 (Estimation of Natural Metal Concentrations in Boulder and Slickrock Creeks)

a. "The most active area of sulfide oxidation is likely within the transition zone which lies between the gossan and the underlying sulfides."

b. "In the model, the natural background concentrations of copper and zinc that are observed in the creeks are a function of the areal extent of gossan outcrops in each respective watershed and the amount of dilution by low-metal surface water."

c. "The quantity of water that reaches the creeks per unit area from each portion of the watershed are assumed to be the same unit area for each area of massive gossan, mineralized bedrock, and non-mineralized bedrock."

d. "[T]he area of disseminated gossan exposed at the surface was used as a conservative estimate for the area of mineralized bedrock in BC and Slickrock basins."

e. "The areal contribution of gossan and disseminated gossan...shown on the geologic maps contained in the work by Kinkel et al. (1956), Weston (1989), and from field mapping by SMI in 1996...."

f. "The copper and zinc concentrations released from areas of disseminated gossan are represented by average concentrations from the mineralized bedrock...."

g. "The average copper and zinc concentrations in the 2:1 water extractions of transect samples [of non-waste landslide material] (copper = 0.025 mg/L; zinc = 0.067 mg/L) are used to represent the concentrations of metals in surface runoff from non-mineralized bedrock."

h. Table 6-2 is a summary of copper and zinc concentrations used in calculations of baseflow metal concentrations in Boulder and Slickrock Creeks.

i. Tables 6-4 and 6-5 list the stream copper and zinc concentrations calculated from the leachates, gossan wells, statistical analysis, and the percent of the load attributed to the natural background concentration. The percent of the copper and zinc load for Boulder Creek is 63 and 17 percent, respectively; and, for Slickrock Creek, 69 and 36 percent, respectively.

Response to Findings in Section 6.0

In this section, SMI explains its model and describes the estimates produced by the model when the data SMI develops in other sections are used as inputs to the model. The model attempts to estimate the "pre-mining" metal load using an area apportionment approach. The model uses the surface area of gossan and disseminated gossan in the watershed to estimate the amount of metal that would be generated by groundwater from those areas. The metals concentrations used by SMI are the groundwater concentrations developed from other sections of the report.

a. It is agreed that the transition zone was the most active area of sulfide oxidation prior to mining, but today the most active area of sulfide oxidation at Iron Mountain is unquestionably the area of the mine workings. The acid mine drainage discharge concentrations and loads are among the most extreme in the world. EPA estimates that the rate of oxidation in the Richmond Mine is more than 1,000 times greater than the rate prior to mining. Moreover, mining activities have changed the characteristics of the transition zone in ways that greatly accelerate the rate of oxidation above the pre-mining condition. Some examples of changes to the transition zone that have likely accelerated the rates of sulfide oxidation and metal release are a descending water table, increased flow of air and free oxygen, and accelerated movement of groundwater through the hydrogeologic system.

SMI does not address the ways in which mining has altered the site. SMI also does not explain how it separates the rate of oxidation that is not affected by mining from the "natural background" component.

b. SMI makes numerous explicit and implied assumptions in its model. Unfortunately, SMI does not examine the effect of the assumptions through a sensitivity or other analysis. More importantly, a review of the assumptions and other inputs to the model reveals that the model will not generate a reliable estimate of pre-mining metal concentrations. It is also important to note that the model does not attempt to determine the current amount of metals that are attributable to the release of metals of a naturally occurring substance in its unaltered form, or altered solely through naturally occurring processes or phenomena, from a location where it is naturally found.

   One explicit assumption is that "the natural background concentrations of copper and zinc that are observed in the creeks are a function of the areal extent of gossan outcrops in each respective watershed and the amount of dilution by low-metal surface water." As explained above, mining has affected the gossan and disseminated gossan in ways that change the rate of release of metals. Thus, although the areal extent of gossan and to a lesser extent disseminated gossan may have been positively correlated with the contribution of pre-mining metal contributions, the extensive perturbations to the site caused by mining and related activities make it impossible to evaluate that hypotheses. The pre-mining metal contributions are overwhelmed by contributions from partially oxidized mineralization whose oxidation rate has been greatly accelerated by the mining activity.

c. The model also assumes that the quantity of water that reaches the creeks per unit area from each portion of the watershed is the same rate per unit area regardless of whether the area includes massive gossan, mineralized bedrock, or non-mineralized bedrock. This assumption, which is fundamental to the SMI model, is wrong because the rock types *differ in their ability to permit the flowthrough of water. Moreover, water flow*ing through gossan and other mineralization is likely to differ substantially in metal concentration. The water flowing though preferential flowpaths would likely be the majority of water associated with gossan. In a pre-mining condition, this water would be relatively clean because the surface of the preferential flowpaths would have become highly oxidized over many thousands to (more likely) millions of years of flow. Water in the transition zone would likely have higher metal concentrations than water in the preferential flow paths, but the water flow rates would likely be lower because of lower permeability in this zone compared with the fully oxidized, extremely porous gossan. If this were not the case, over geologic time all of the sulfide mineralization in the area would have already been completely oxidized. Thus, whereas SMI assumes a homogeneous flow through various rock types, there is significant variability in water flow and metal concentration even within one type of rock. These variations are even more significant because the variations in flow affect the concentration of metal in the groundwater associated with each rock type. The effect of this assumption is a gross overestimation of pre-mining metal loads.

d. SMI uses the area of disseminated gossan exposed at the surface to estimate the area of mineralized bedrock in the Boulder and Slickrock Creek basins. The mineralized bedrock concentrations are used to represent the supposed sulfides below the "disseminated gossan." SMI has failed to adequately support this assumption (see Response

4.d). The use of the area of "disseminated gossan" to indicate subsurface solids is not a conservative approach in that the mapped disseminated gossan may or may not represent subsurface sulfides in the bedrock that could contribute a load to the groundwater system. Thus, even if the disseminated gossan is assumed to be associated with subsurface sulfides, it would be more appropriate to reduce the average contribution by at least 50 percent.

e. Figure 3-1 should show what data are from Kinkel, et al., 1956, and what data have been added by Weston and SMI.

f. As explained in Subparts 4.d and 6.d above, using the areal extent of disseminated gossan as a proxy for the amount of mineralized bedrock introduces substantial uncertainty into the model and is not reasonable.

The leachate values for disseminated bedrock most likely overstate the metal concentration of waters in the bedrock because leachate tests do not accurately reflect field conditions. See Subpart 4.d, above.

SMI has also overstated the results of the leachate test results for bedrock. As discussed above, SMI concludes that the average leachate values for the mineralized bedrock are 23.8 mg/L copper and 5.5 mg/L zinc, but a more appropriate analysis indicates that these leachate test values should at least be reduced to 9.6 mg/L copper and 5.7 mg/L zinc and those values should be used only in the transition zone, with significantly lower concentrations for other groundwater. Groundwater sampling suggests that adsorption reduces the concentrations to 1.3 mg/L copper and 1.2 mg/L zinc. These figures might also overstate the pre-mining metal concentrations in the transition zone because the sampling locations are in an area that has been impacted by mining.

It is also important to note the dramatic difference between the leachate data for the mineralized bedrock and the disseminated gossan. The five samples of "disseminated gossan" leachate averaged only 0.021 mg/L copper and 0.036 mg/L zinc. These figures are substantially below the leachate test results for mineralized bedrock used by SMI (23.8 mg/L copper and 5.5 mg/L zinc). These data suggest that the disseminated gossan areas were not significant natural sources of metals in the undisturbed pre-mining state.

g. SMI estimates the concentrations of metals in surface runoff from non-mineralized bedrock using the average copper and zinc concentrations in the 2:1 water extractions of transect samples [of "non-waste" landslide material] (copper = 0.025 mg/L; zinc = 0.067 mg/L). The supposedly non-mineralized copper concentration of 0.025 mg/L and zinc concentration of 0.067 mg/L are higher than the "disseminated gossan" leachates. This does not make sense because one would expect metals to be higher in mineralized areas than in non-mineralized areas. In fact, the concentrations calculated by SMI are several times higher than surface water even from mineralized areas. For example, above Boulder Creek Falls, the copper concentrations in surface water are less than 0.005 mg/L (or 25 percent of the SMI estimates); the zinc concentrations in surface waters are less than 0.030 mg/L (or 50 percent of the SMI estimate). Even these concentrations overstate non-mineralized metal concentrations because the area contains massive and disseminated gossan. This type of obvious error and bias by SMI seriously undermines the credibility of the study. In the model, SMI should use values from surface water measurements in a non-mineralized area and above the first source of mineralization (*or* even 1 μg/L copper, as found in Whiskeytown Lake). At this point, the areal weighting can begin in the lower part of the creeks.

h. The SMI estimates of groundwater metal concentrations are based upon (1) gossan groundwater sampling data, (2) gossan leachate data, (3) PCA/SDA statistical analysis, and (4) transition zone bedrock analysis. As discussed above, SMI has greatly overestimated the concentrations associated with undisturbed mineralization in its natural condition. Even accepting that some of the data collected by SMI could be assumed to represent the pre-mining condition, the data should be revised to account for the effects of mining. Simply removing one of the obviously impacted wells (SMI-01) reduces the average concentrations to 1.3 mg/L for copper and 1.2 mg/L for zinc. While these figures are substantially less than those used by SMI (copper 8.5 mg/l [well data], 27.5 mg/L [leach tests], and 5.7 [PCA/SDA]; and zinc 4.33 mg/L [well data], 12.05 mg/L [leach tests], and 8.5 mg/L [PCA/SDA]), the estimates are still probably high by one or two orders of magnitude. This is because of problems inherent in the test methods and the very great likelihood that mining has changed conditions at the sampling locations.

i. The SMI model also assumes that the average copper and zinc that was found in the leachates and groundwater is transported to the creeks. This assumption ignores the natural processes that permitted the mineral deposit in the gossan to be formed in the first place. The copper concentration in the groundwater will be attenuated by both adsorption and precipitation. It has been demonstrated that as much as 50 percent of the copper even in surface runoff does not reach the creeks (see the technical memorandum responding to *Chemistry, Mineralogy, and Potential Metal Loading of Surface Salts*, by Shepherd Miller, Inc., dated October 27, 1995); groundwater should attenuate the copper concentration even more. Therefore, if metal-bearing water enters the surface through seeps, probably at least half of the copper will be adsorbed before it reaches the creeks. Secondly, precipitation of secondary copper sulfide minerals (i.e., chalcocite) will further attenuate the copper concentration. This secondary mineral forms a copper-enriched supergene blanket above fresh sulfides and further controls the transport of copper at the massive sulfide source (SMI identified this mineral in one core, but ignored the process in its model).

The model does not provide a reliable estimate of releases associated with a release of metals of a naturally occurring substance in its unaltered form, or altered solely through naturally occurring processes or phenomena, from a location where it is naturally found. The model contains too many overly simplistic assumptions, and the inputs to the model greatly overpredict contribution of undisturbed mineralization or the premining concentration of metal at the site. The model likely overstates the load of metals generated by Iron Mountain by at least several orders of magnitude.

When the model is tested using a mineralized area of Iron Mountain that has not been extensively mined, the model overpredicts the actual copper concentrations by a factor of about 500, and the zinc concentrations by a factor of about 48. See the technical memorandum re *Evaluation of the SMI Methodology for Estimating "Natural Copper and Zinc Concentrations" Applied to the Catfish Pond Area, Iron Mountain Mine*. Thus, the model does not provide a reliable estimate of pre-mining conditions.

Findings in Section 7.0 (Calculations Based on Published Sulfide Oxidation Rates)

a. Calculations were performed to determine if the observed and predicted amounts of copper and zinc loading to Boulder and Slickrock Creeks are consistent with published rates of sulfide weathering.

b. The assumptions stated in the calculations are:

- The average thickness of the active sulfide oxidation zone is 1 meter.
- The average amount of sulfide in the transition zone is 60 percent.
- The density of the sulfide minerals in the transition zone is equal to the average density of the massive sulfide ore (275 lb/cubic foot).
- The surface area of the sulfide particles corresponds to particles with an average diameter of 1.5 mm.
- Copper comprises approximately 3.5 percent of the ore.
- Zinc comprises 3.5 percent of the ore.

c. A series of equations purports to calculate the maximum copper and zinc loading to Boulder and Slickrock Creeks, and these calculated results may be conservatively low.

Response to Findings in Section 7.0

In this section, SMI makes a number of assumptions and uses published sulfide weathering rates to develop a qualitative estimate of copper and zinc flux. Unfortunately, the underlying assumptions are incorrect, so the analysis is not of use.

a. In these calculations, SMI uses the published rate for the oxidation of pyrrhotite. This is confusing because the ore deposit at Iron Mountain consists mainly of pyrite and chalcopyrite, with only a small amount of pyrrhotite. The reference upon which SMI relies in fact contrasts the oxidation of pyrrhotite to that of pyrite. The authors of SMI's reference state that the oxidation rate of pyrite is 20 to 100 times slower than the oxidation rate for pyrrhotite; therefore, SMI's estimate is one to two orders of magnitude too high from the beginning (according to SMI's reference). A subsequent reference indicates that the oxidation rate from the text upon which SMI relies for a mixture of pyrite and chalcopyrite may be about right (when temperature is considered), but SMI's text needs to better address what is being oxidized and use the correct oxidation rate for the Iron Mountain mineralization.

b. The one-meter thickness of active oxidation on a grain-by-grain basis is at least two times, if not an order-of-magnitude, too high because the actual oxidation in the transition zone is caused by the oxidizing water moving only in the fractures, not as porous media. The effect of this error is to overestimate the oxidation rate by a factor of two to ten times.

   The assumed average of 60 percent sulfide over a thickness of one meter needs further documentation. This may be true in some areas, but it is probably not true over the entire area. The order in which this 60 percent is applied in the calculations produces misleading results. The 60 percent is applied at the end of the calculation sequence, where the loads per day are calculated. This number needs to be added to the first equation along with a weighting factor that takes into account the permeability based on fracture geometry, not that of a porous medium.

c. The first equation assumes a cubic meter of pyrite with a density of 275 pounds per cubic foot is being oxidized when, at best, only about 30 percent (maybe only 6 percent or less) of the sulfide is being oxidized (fracture flow path correction).

The second and third equations calculate the surface area of 0.15-cm cubes making up a cubic meter of pyrite. The fourth equation then uses the oxidation rate of pyrrhotite to determine the moles of pyrite being oxidized per cubic meter of ore. There are several mistakes here. For this model to be true, cubes of pyrite (0.15 cm on a side) would be individually floating approximately 0.15 mm from each other. It is difficult to envision the entire surface of each pyrite cube being exposed to oxygenated water (pyrite cubes do not float). The initial oxidation would plug off the flow of groundwater through the cubic meter of ore. So at least one and a part of at least four other faces of the pyrite cubes must be shielded from the oxygenated water by attachment to the rhyolite ground mass (about 40 plus percent of the real mass). Maybe approximately half of the surface area of the pyrite will actually be initially exposed to oxidation, but after the oxidation of the first layer of sulfide, the oxidation has to proceed through progressively thicker rims of iron oxyhydroxide and iron oxide, so the oxidation rate actually decreases with time. The equations in the model are therefore more indicative of mining activities rather than undisturbed mineralization because the surface area estimates are more consistent with oxidation of a crushed ore or tailings material.

The fourth and fifth equations calculate the pounds of copper and zinc, respectively, that the cubic meter of sulfide would produce, assuming 3 percent copper and 3.5 percent zinc is present in the sulfide. This further assumes that the oxidation rate does not change and that all of the copper and zinc are transported into the groundwater system. The oxidation rate will decrease with time and may essentially cease when the diffusion rate across the iron oxyhydroxide and oxide is too slow to allow further oxidation of the sulfide (the reason for sulfides occurring in the gossan). Furthermore, release and transport of zinc is probably almost complete if the pH stays low, but copper transport is entirely different. A portion of the dissolved copper migrates into the remaining sulfide to form secondary copper sulfide minerals, which enrich the massive sulfide with a supergene blanket of higher grade copper ore than is present in the original massive sulfide. Another portion of the copper will be adsorbed to the iron oxyhydroxide coating particles in the vicinity of the release, unless the pH remains below about 3 or 4, the pH beneath which copper is not adsorbed. This is the case with the massive sulfides exposed in the mine workings. However, chemical reactions between the sulfuric acid created by the oxidizing sulfide and the rhyolite and/or greenstone in the transition zone may increase the pH locally (perhaps to values of about 5 or 6) and thereby also increase the amount of the dissolved copper adsorbed to the precipitated iron oxyhydroxide. Therefore, there are two copper-retaining mechanisms which need to be considered for transition zone oxidation. By ignoring these mechanisms, SMI has calculated the post-mining discharge rates because the conditions being modeled reflect dissolved copper and zinc that would be expected from the exposed massive sulfide in the mine workings, including the crushed ore and muck piles.

Finally, the last four equations use the previous equations to estimate the pounds of copper and zinc per day for both Boulder and Slickrock Creeks assuming that a 1-meter thickness of the transition zone is comparable to 60 percent of the rate of release from a massive sulfide. At best, this estimate is for the oxidation of pyrite continuing at the oxidation rate of a fresh pyrrhotite until the massive sulfide is completely oxidized. If the oxidation rate had been that of pyrite and chalcopyrite, this would be about what would be expected from the mine workings where the walls exposed 60 percent massive sulfide and 40 percent rhyolite and the sulfuric acid from the oxidation does not chemically react with the rhyolite. The calculated loadings are not even "conservatively low" for a fresh massive sulfide. They are exceedingly high (at least two orders of magnitude) for small pyrite grains in a matrix of rhyolite with oxidation occurring along fractures in the rhyolite. As a result, the equations provide no information concerning the level of pre-mining discharges and are in fact much more indicative of mining-related impacts.

Findings in Section 8.0 (Toxicity Estimates)

Calculated natural copper and zinc concentrations in both Boulder and Slickrock Creeks would have exceeded the U.S. EPA aquatic toxicity standards during all seasons of the year.

Response to Findings in Section 8.0

Field investigations and molecular genetics (DNA) studies conducted by EPA indicate that, prior to mining, Boulder and Slickrock Creeks were capable of supporting a diverse aquatic community. The presence of diverse aquatic communities above the chemical barrier that exists at Iron Mountain indicate that the SMI estimates are wrong. Refer to *Iron Mountain Region Fall 1996 Stream Biota Preliminary Study*, November 27, 1996, Slotton, D. G., S. M. Ayers, and C. R. Goldman, Ecological Research Associates; and *Molecular Genetics of Rainbow Trout (Onorhynchus mykiss) and California Roach (Hesperoleucus symmetricus) in the Vicinity of Iron Mountain*; Nielsen, J. L., 1996.

Findings in Section 9.0 (Summary)

"There is an abundance of data which shows the natural oxidation of sulfide minerals has occurred within the rocks at Iron Mountain for tens of thousands to several million years and is still actively occurring." "The best estimates of natural background concentrations of copper and zinc during summer low-flow conditions, range from 1.04 to 5.0 mg/L (copper) and 0.79 to 2.2 mg/L (zinc) for both Boulder and Slickrock Creeks."

Response to Findings in Section 9.0

SMI has obviously not calculated how long the entire pre-mining massive sulfide orebody would last if the natural background discharge rate <u>estimates</u> were in fact the <u>actual</u> pre-mining background. The acid test of any estimate is whether it makes sense. In this case, the ore deposit could not have existed for even 50,000 years, let alone millions of years, if the oxidation of the orebody were such as to have SMI's estimated natural background discharge rates. SMI's estimated background concentrations are probably more than two orders of magnitude too high.

Dr. Charles Alpers, USGS, calculated hypothetical rates of gossan formation and sulfide ore consumption from information available regarding the physical and chemical characteristics of Iron Mountain sulfide deposits. Dr. Alpers then applied SMI's estimates of the copper flux rates (a total of approximately 53,000 lb/yr) to estimate the length of time it would take to produce the volumes of gossan that were present at Iron Mountain, on the basis of available mining records, with an allowance for loss over time from erosion. If the SMI copper flux rates are accurate, Dr. Alpers' calculation is that the gossan deposit could only be approximately 42,000 years old. Paleomagnetic data indicates that the gossan would have been exposed for at least 780,000 years (and probably much longer). This information, coupled with the general understanding of the manner in which the deposit at Iron Mountain became exposed through geologic processes, provides very strong evidence that the SMI estimates of "natural" oxidation rates are wrong.

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Review of Preliminary Determination of Background Copper Concentrations in Boulder and Slickrock Creeks

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Description of Document

This document, *Review of Preliminary Determination of Background Copper Concentrations in Boulder and Slickrock Creeks, Iron Mountain Area, Shasta County, California* (Shepherd Miller, Inc. [SMI], September 14, 1995 [SMC Vol. 28, Tab 9]), is a preliminary set of individual draft reports initiating a program to determine background copper concentrations in Boulder and Slickrock Creeks, in the Iron Mountain vicinity.

The document is superseded by the June 28, 1996, final report, which includes zinc concentrations, generally enhances the draft reports in this preliminary document, and includes additional individual reports. See also the technical memorandum responding to the *Determination of Natural Background Metals Concentrations in Boulder and Slickrock Creeks*, by Shepherd Miller, Inc., dated July 29, 1996.

Major Findings or Major Review Comments in Document

Finding A

The document contains preliminary estimated copper concentrations for both creeks from published literature values (Section 2.0, Survey of Existing Literature), copper concentrations in water from wells and gossan, leaching studies of gossan material, a statistical analysis (principal component and a stepwise discriminant analysis) of site surface and groundwater, baseflow concentrations for "natural" winter high-flow versus "natural" summer low-flow conditions, and an estimate of "natural" concentration toxicity.

Finding B

The predicted range for "natural background" copper concentrations for winter high-flow conditions in Slickrock Creek is from 0.2 to 0.94 milligrams per liter (mg/L); in Boulder Creek, this range is from 0.12 to 0.69 mg/L. Summer low-flow conditions "natural background" concentrations range from 0.83 to 4.3 mg/L in both creeks. These values are in agreement with observed summer and winter concentrations in Boulder Creek. These values are also within the range of copper concentrations for "mineralized, non-mined" areas (<0.001 to 68 mg/L).

Finding C

"Unpublished data from the sites near the Mammoth Mine in the Shasta Mining District that have not been disturbed by mining show concentrations of copper from 0.63 to 2.6 mg/L."

Finding D

These data "show that the aquatic toxicity standards would have been exceeded by the natural concentrations of copper in both Slickrock Creek and Boulder Creek prior to mining."

Response to Major Findings in Document

Response A

The major findings do not significantly differ from the final report referenced above, and the comments on that report are appropriate for this report. The reader is referred to those comments for a more complete response to SMI's major findings. See the technical memorandum responding to the *Determination of Natural Background Metals Concentrations in Boulder and Slickrock Creeks*, by Shepherd Miller, Inc., dated July 29, 1996.

Response B

One of the key problems with the SMI report (both draft and final) is that SMI has confused "natural baseline" with the current "baseline concentration." SMI calculates the "baseline concentration" but claims to be calculating "natural background." The term "background" is usually considered to refer to the natural, undisturbed concentration of either mineralized or non-mineralized conditions. The term current "baseline concentration" refers to current metal concentrations at a site. The term "natural baseline" could refer to the pre-mining background, but this is not what SMI has calculated in this report. The bottom line is that the "natural background" ranges calculated by SMI are actually concentration ranges for disturbed mineralization.

Response C

It would be difficult to locate and sample any drainage area within the Shasta Mining District that is totally unimpacted by mining to some degree. This report does not indicate where the referenced water samples were collected, why those locations were chosen, or when they were sampled. Information from the final report indicates that the sampling locations were from areas close to extensive mining activities, making it likely that the sampling locations have been impacted by mining to variable degrees. For example, review of topographic maps indicates mining disturbances throughout the drainages in the area, including exploratory holes, secondary mine roads, and mine workings.

Response D

The concentration estimates in the report are based upon data collected from disturbed materials or from intrusive methods that disturbed material. It is therefore not surprising that the copper concentration ranges exceed the aquatic standards.

Similarly, the statistical methods used by SMI merely indicate differences in disturbed materials from several sources within the mining area. The analysis does not reveal whether a particular group represents pre-mining conditions. In addition, there are no data representing the pre-mining conditions, so it cannot be determined whether any of the samples represent conditions undisturbed by human activity.

Evaluation of the SMI Methodology for Estimating "Natural Copper and Zinc Concentrations" Applied to the Catfish Pond Area, Iron Mountain Mine

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Shepherd Miller, Inc. (SMI) presents its estimation of the "natural" dissolved copper and zinc concentrations in Boulder and Slickrock Creeks in the report entitled *Determination of Natural Background Metals Concentrations in Boulder and Slickrock Creeks, Iron Mountain Area, Shasta County, California*. The report, dated June 28,1996, was produced by SMI for Stauffer Management Company. This memorandum evaluates the accuracy of SMI's assumptions and methodology and the value of SMI's approach as a predictive tool, by comparing the actual measured dissolved copper and zinc concentrations found in surface water samples in Upper Slickrock Creek with the concentrations predicted using the SMI methodology.

Summary

Comparison of actual surface water metal concentrations from Upper Slickrock Creek with concentrations predicted using the SMI method shows that the SMI method is not useful for determining pre-mining metal concentrations. As demonstrated in the analysis presented in this memorandum, the SMI approach overestimates the dissolved copper concentrations by about 500 times, and the dissolved zinc concentrations by about 48 times when compared with actual measured concentrations obtained from analytical testing of surface water samples. A summary of the results of this analyses is presented in Table 1.

Table 1
Comparison of Measured Copper and Zinc Concentrations for Upper Slickrock Creek with Concentrations Computed Using the Shepherd Miller Methodology

Location	Number of Samples	SCDD Inflow (cfs)	Dissolved Copper (µg/L)	Dissolved Zinc (µg/L)
Measured Surface Water Concentrations High flow condition	5	130 to 737	3.7 to 9.4	17.3 to 33.8
Measured Surface Water Concentrations Low flow condition	4	4 to 15	5.1 to 26.3	28.5 to 63.8
Shepherd Miller Method Concentrations High winter flow condition	N/A	N/A	2,420 to 4,120	850 to 1,450

Application of the SMI Methodology to Upper Slickrock Creek

The SMI methodology was used to predict dissolved copper and zinc concentrations of surface water at a point just downgradient of Catfish Pond in Upper Slickrock Creek. The area is well suited for evaluating the SMI approach in that it is isolated from upstream surface water by the Upper Slickrock Clean Water Diversion. Surface water has been collected just downstream of Catfish Pond as part of EPA's surface water sampling program during the period from December 1995 through January 1997. The location of Catfish Pond in the Upper Slickrock Creek Basin is shown in Figure 1. The drainage area boundaries and the basemap shown in Figure 1 were provided by the SMC consultant Roy F. Weston (1994).

SMI identified gossan formations above Catfish Pond as a source of copper and zinc contamination in its June 28, 1996, report. Figure 2 presents a reproduction of the SMI figure (Figure 3-1) delineating massive and disseminated gossan in the Upper Slickrock Creek Basin and the Roy F. Weston drainage area boundaries. Locations 1, 2, and 3, shown on Figures 1 and 2, are the gossan areas in the Catfish Pond drainage area. Locations 4 and 5 are gossan areas above Catfish Pond intercepted by the Upper Slickrock Creek diversion.

The Catfish Pond area is well suited for evaluating potential copper and zinc discharges associated with undisturbed gossan formations. As shown in Photo Exhibits 1 and 2, the gossan above Catfish Pond is in-place and appears relatively undisturbed, in stark contrast to the SMI wells and seep locations which are either within or in close proximity to the Brick Flat Pit open pit mine. Figure 2 shows the approximate areas showing the Photo Exhibits locations.

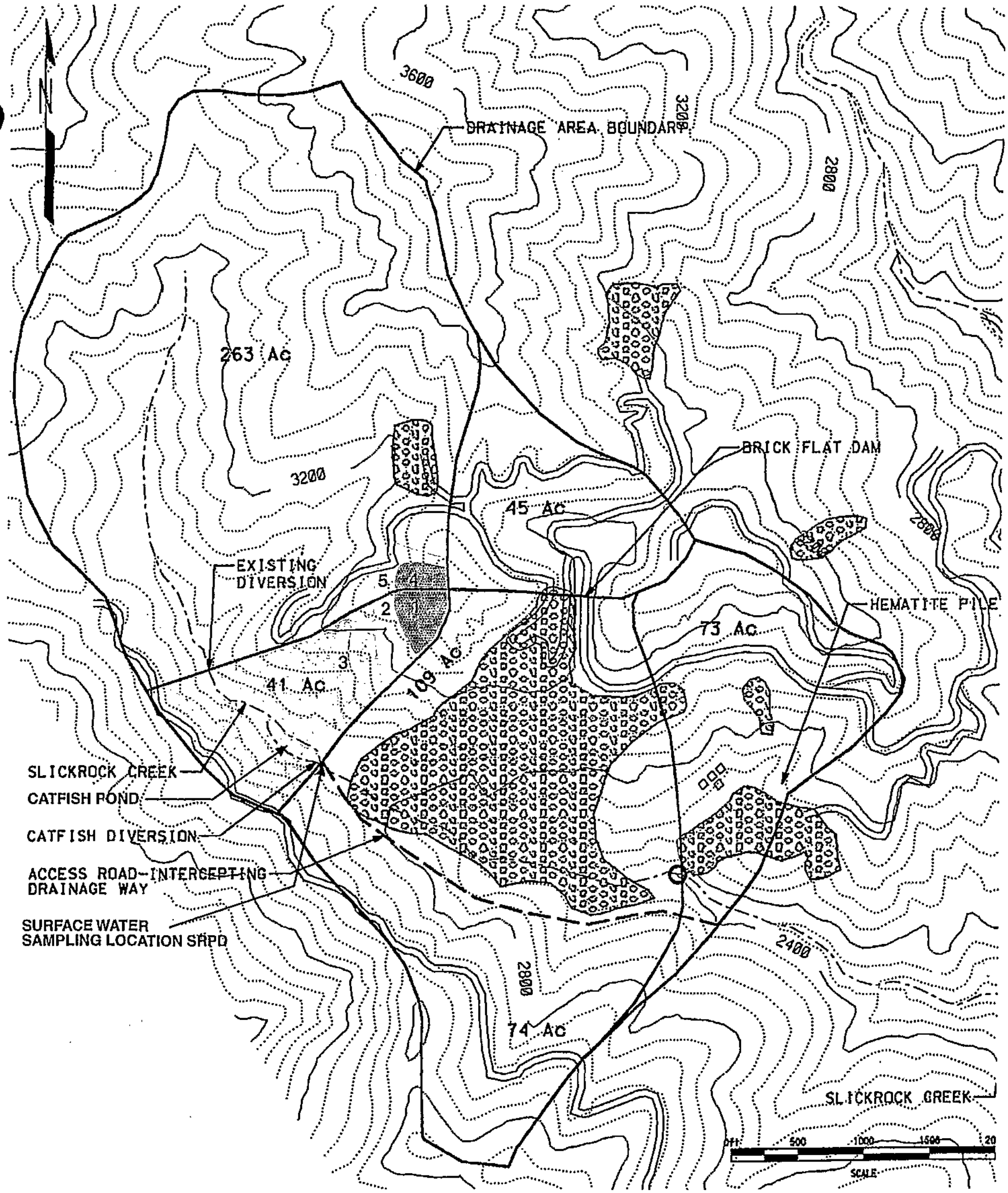
SCDD inflows are presented in Table 1 as an indication of the magnitude of the flows in the Upper Slickrock Creek drainage area at the time that surface water samples were collected. On the days that the samples were collected, the capacity of the Upper Slickrock Creek diversion was not exceeded; all flow from upper Slickrock Creek was routed around the Catfish Pond drainage. Thus the water samples collected for laboratory testing are representative of surface water discharging locally from the immediate Catfish Pond drainage area. The individual analytical laboratory sample results are presented in Attachment C.

The approach described below and detailed in Attachment A uses the SMI methodology for Winter High-Flow conditions. For these conditions, SMI assumes that for each inch of precipitation that enters the massive gossan, 1 inch of gossan water is displaced and enters the drainage basin, where it is diluted by 1 inch of surface runoff. SMI calculates the concentrations of copper and zinc in Slickrock Creek that "are attributed to natural sources (C_{final})" using the following equation.

$$C_1V_1 + C_2V_2 + C_3V_3 = C_{final}V_{final}$$

Where:

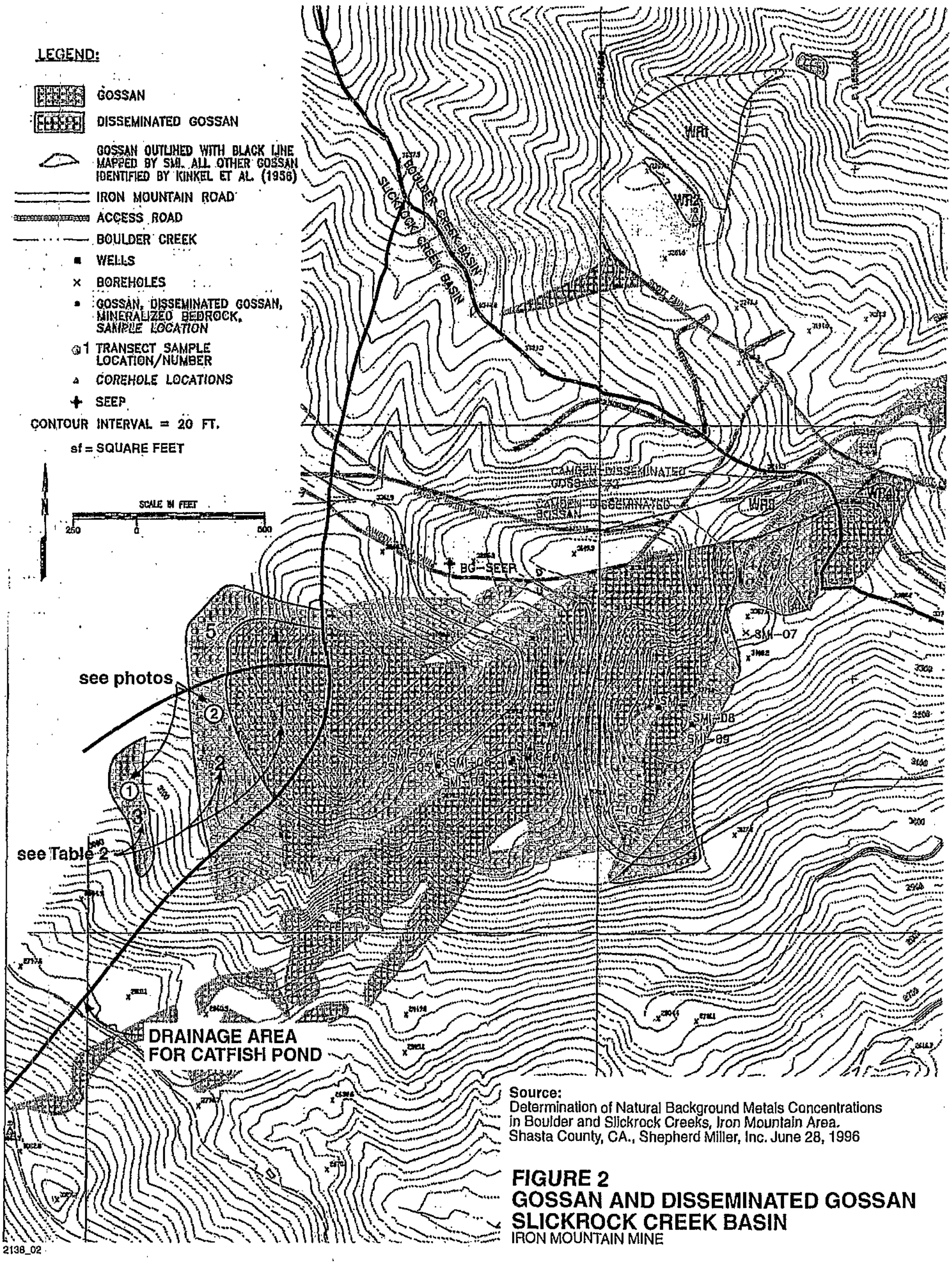
C_1 = Concentration of copper or zinc in the massive gossan water (from leaching studies, Cu = 27.5 mg/L and Zn = 12.05 mg/L, from gossan wells, Cu = 8.5 mg/L and Zn = 4.33 mg/L, from statistical analysis, Cu = 5.7 mg/L and Zn = 8.5 mg/L; see SMI Table 6-2 reprinted in Attachment B)



BASE MAP AND DRAINAGE AREA BOUNDRIES FROM:
FOCUSED FEASIBILITY STUDY REPORT FOR THE MITIGATION OF ACID MINE DRAINAGE RELEASES FROM THE IRON MOUNTAIN MINE SITE NEAR REDDING, CALIFORNIA, Roy F. Weston, 1994

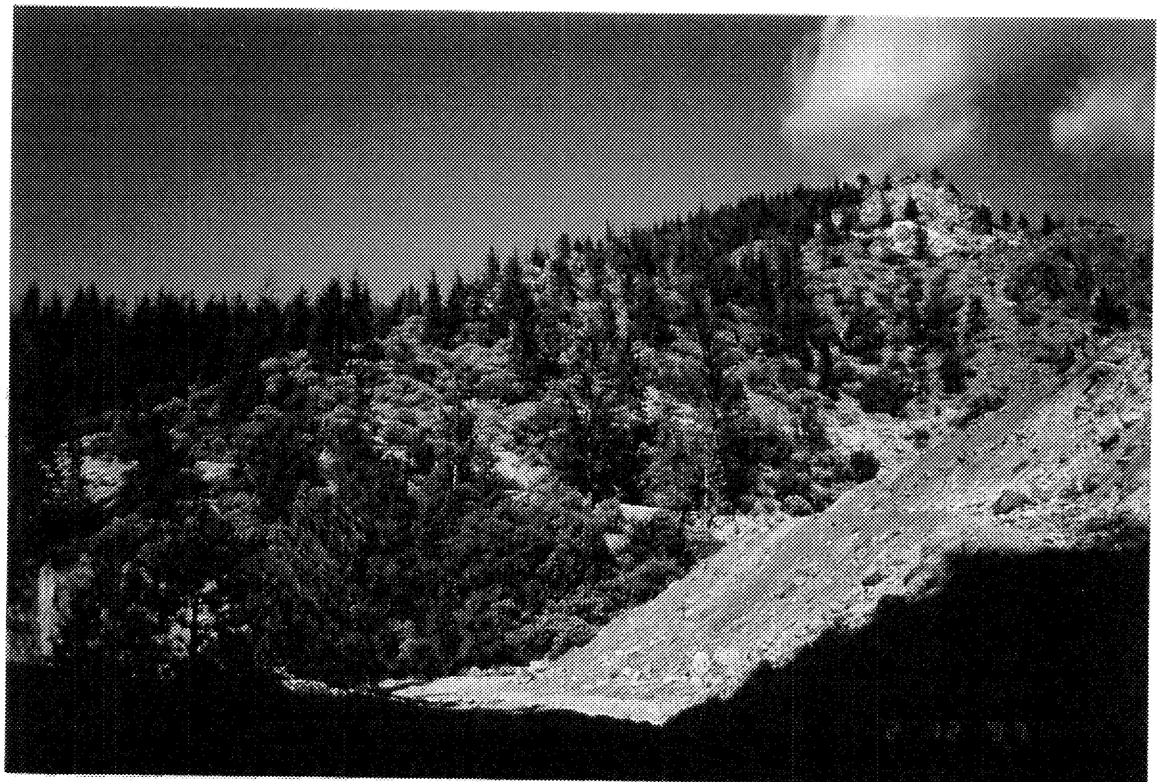
FIGURE 1
DRAINAGE AND GOSSAN AREA FOR CATFISH POND UPPER SLICKROCK CREEK
IRON MOUNTAIN MINE

2160_01

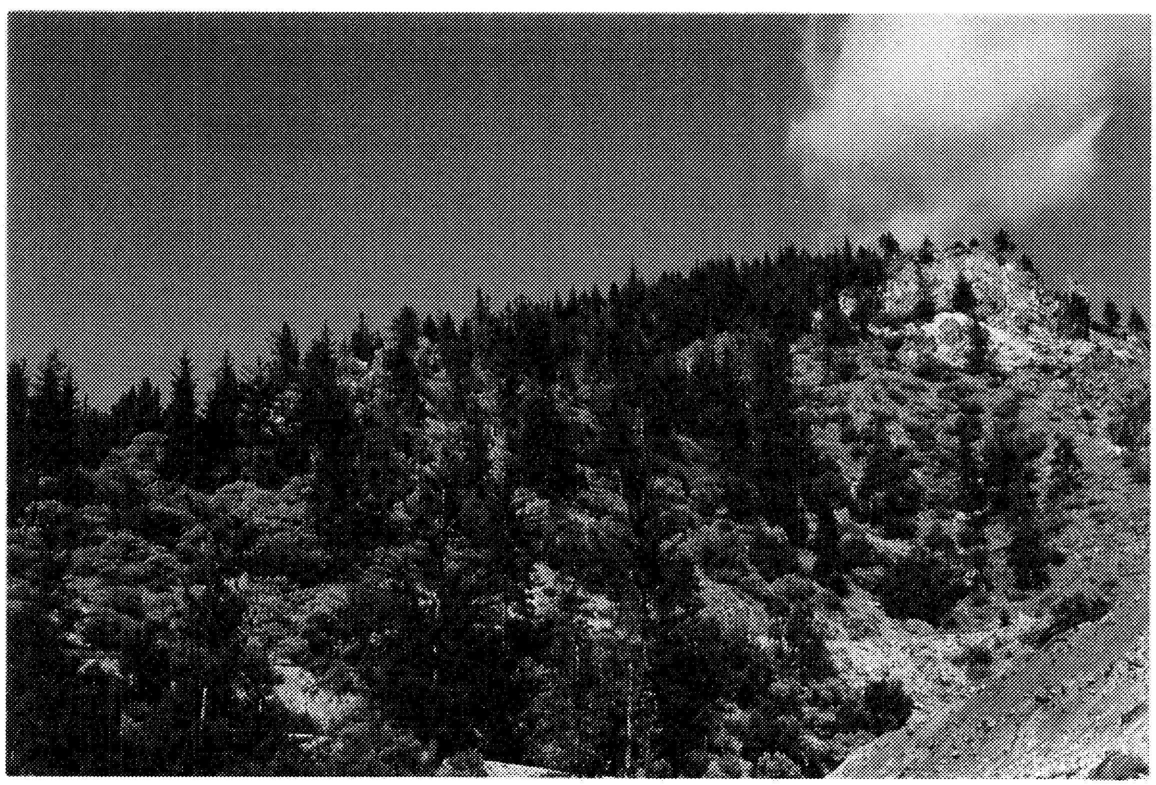


Source:
Determination of Natural Background Metals Concentrations in Boulder and Slickrock Creeks, Iron Mountain Area. Shasta County, CA., Shepherd Miller, Inc. June 28, 1996

FIGURE 2
GOSSAN AND DISSEMINATED GOSSAN
SLICKROCK CREEK BASIN
IRON MOUNTAIN MINE

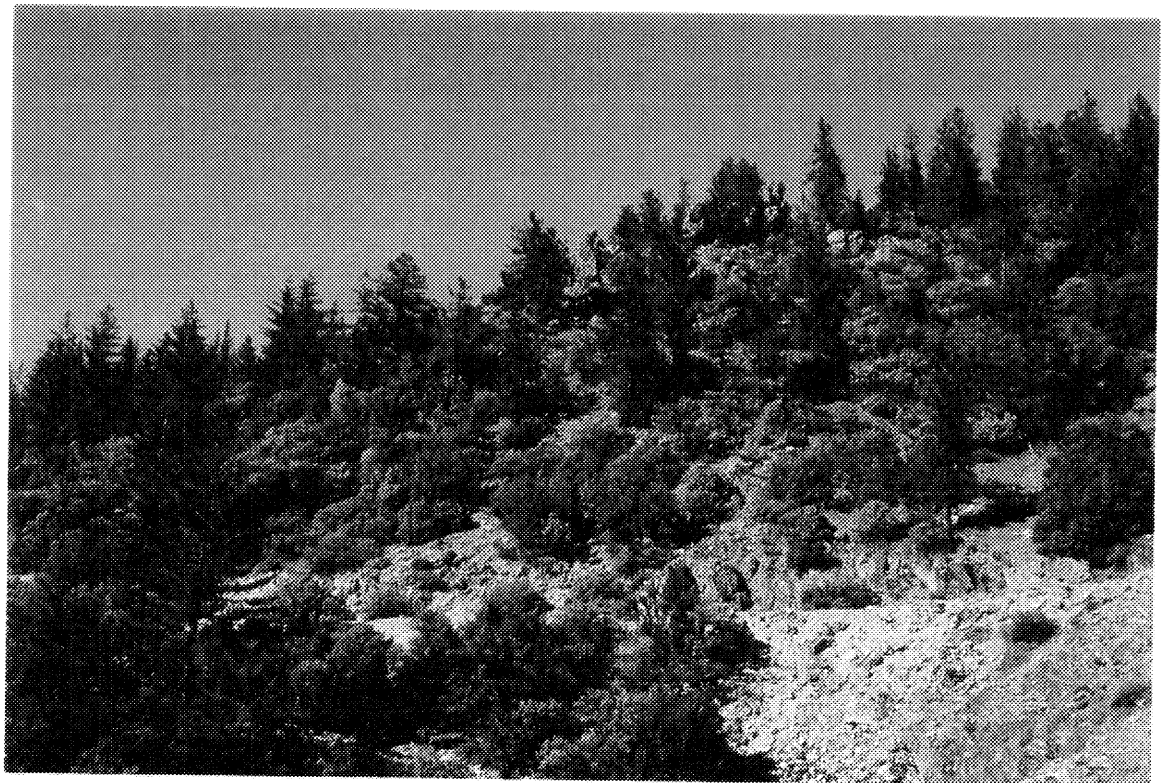


Refer to Figure 2 Area ② for Approximate Location
February 12, 1997



Refer to Figure 2 Area ② for Approximate Location
February 12, 1997

PHOTO EXHIBIT 1
GOSSAN ABOVE CATFISH POND
IRON MOUNTAIN MINE



Refer to Figure 2 Area ① for Approximate Location
February 12, 1997

Refer to Figure 2 Area ① for Approximate Location
February 12, 1997

PHOTO EXHIBIT 2
GOSSAN ABOVE CATFISH POND
IRON MOUNTAIN MINE

V_1 = Volume of massive gossan water displaced by 1 inch of rainfall (equals the area of massive gossan multiplied by 1 inch of rainwater)

C_2 = Concentration of copper or zinc in the mineralized bedrock water (Cu = 19.9 mg/L and Zn = 4.66 mg/L; see SMI Table 6-2 reprinted in Attachment B)

V_2 = Volume of mineralized bedrock water displaced by 1 inch of rainfall (equals the area of disseminated gossan multiplied by 1 inch of rainwater)

C3 = Concentration of copper or zinc in the surface runoff (Cu = 0.025 mg/L and Zn = 0.067 mg/L; see SMI Table 6-3 reprinted in Attachment B)

V_{final} = Total volume of 1 inch of rainfall over the entire drainage area, including massive gossan, mineralized bedrock, and surface runoff.

The SMI report shows gossan and disseminated gossan areas flanking the Catfish Pond drainage channel. These areas were included in the SMI calculation of "natural copper and zinc concentrations" for the entire Slickrock Creek basin. The drainage areas and the gossan areas shown in Figures 1 and 2 are listed in Table 2.

Table 2
Computed Catfish Pond Drainage Area, Gossan Area, and Disseminated Gossan Area

Location	Drainage Area (square feet)	Massive Gossan (square feet)	Disseminated Gossan (square feet)
Slickrock Creek Drainage [a]	6.13×10^7	1.590×10^6	9.784×10^5
Catfish Pond Drainage [b]	1.873×10^6	387,500	344,900
Area 1: Massive Gossan [b]		139,000	
Area 2: Disseminated Gossan [b]			121,000
Area 3: Disseminated Gossan [b]			54,000
Area 4: Massive Gossan [b]		66,000	
Area 5: Disseminated Gossan [b]			85,000

[a] Areas given in *Determination of Natural Background Metals concentrations in Boulder and Slickrock Creeks, Iron Mountain Area, Shasta County, California*, Shepherd Miller, Inc. June 28, 1997 (Table 6-1)

[b] Areas of drainage from Roy F. Weston (1994); areas of gossan and disseminated gossan measured by computer from Figure 3-1 of SMI's report. Areas are shown in Figure 1 and 2.

Using these surface areas and the SMI assumptions and methodology, the predicted "natural copper and zinc concentrations" were calculated for the Catfish Pond area. Detailed calculations are presented in Attachment A. The range of surface water concentrations predicted using the Shepherd Miller approach listed in Table 1 (2,420 µg/L to 4,120 µg/L for dissolved copper) was computed using the using the SMI assumptions for average copper and zinc concentrations from the SMI Leaching Studies, the SMI Gossan Well Water Average, and the SMI Statistical Analysis Average Copper Concentration.

ATTACHMENT A

Calculations

Copper and zinc concentrations estimated in surface water below Catfish Pond using surface areas, methodology, assumptions, and concentrations from *Determination of Natural Background Metals Concentrations in Boulder and Slickrock Creeks, Iron Mountain Area, Shasta County, California*, Shepherd Miller Inc., June 28, 1996 (Section 6) (Estimation of Natural Metals Concentrations in Slickrock Creek and Boulder Creek).

General SMI Approach: Copper concentration calculated from simple dilution equation:

$$C_f\, V_f = C_1\, V_1 + C_2\, V_2 + C_3\, V_3$$

Where:

C_1 = The concentration of copper or zinc in the massive gossan water (varies according to average concentrations in well waters, leaching experiments, and statistical analyses, so that a range of copper and zinc concentrations is determined) (Table 6-2)

C_2 = The concentration of copper or zinc in the mineralized bedrock water (disseminated gossan water), Table 6-2

C_3 = The concentration of copper or zinc in the surface runoff using the water-extractable metal data from Table 6-3 (constant)

V_1 = The volume of massive gossan water displaced by 1 inch of rainfall (constant for each basin, equals the area of massive gossan multiplied by 1 inch of rain water)

V_2 = The volume of mineralized bedrock water displaced by 1 inch of rainfall (constant for each basin, equals the area of disseminated gossan multiplied by 1 inch of rain water)

V_3 = The volume of runoff water produced by 1 inch of rainfall in the basin, not including the area of the massive gossan and mineralized bedrock gossan (constant for each basin)

C_f = The concentrations of copper and zinc in Boulder and Slickrock Creeks that are attributed to natural sources

V_f = The total volume of 1 inch of rainfall over the area of the entire drainage basin, including massive gossan, mineralized bedrock, and surface runoff (constant for each basin)

I. Catfish Pond Drainage Area—No Mixing with Diversion Water

Total Area = $1.7835 \times 10^6\, ft^2$

V_f = Total Volume Water = $1.7835 \times 10^6\, ft^2\, (0.083\, ft) = 1.480 \times 10^5\, ft^3$

V_1 = Volume Gossan Water = $1.39 \times 10^5\ (0.083\ ft) = 1.1537 \times 10^4\ ft^3$

V_2 = Volume Disseminated Gossan Water = $1.750 \times 10^5\ (0.083\ ft) = 1.4525 \times 10^4\ ft^3$

V_3 = Volume Dilution Water = $V_f - (V_1 + V_2)$

$= 1.480 \times 10^5\ ft^3 - (1.1537 \times 10^4\ ft^3 + 1.4525 \times 10^4\ ft^3)$

$= 1.2194 \times 10^5\ ft^3$

II. Predicted Copper Concentrations C_1 and C_2, Table 6-2, C_3, Table 6-3; Attachment B

a. Leaching Studies Average

$$C_f\ V_f = C_1\ V_1 + C_2\ V_2 + C_3\ V_3$$

$$27.5\ mg/L\ (1.537 \times 10^4\ ft^3) + 19.9\ mg/L\ (1.4525 \times 10^4\ ft^3) + 0.025\ mg/L\ (1.2194 \times 10^5\ ft^3)$$

$$C_f\ (1.480 \times 10^5\ ft^3) = 3.173 \times 10^5 + 2.890 \times 10^5 + 0.0305 \times 10^5$$

$C_2\ V_2 + C_3\ V_3 = 2.921 \times 10^5$ (Does not change for II.b and II.c.)

$$C_f = \frac{3.173 \times 10^5 + 2.921 \times 10^5}{1.480 \times 10^5}$$

$$\boxed{C_f = 4.12\ mg/L = 4{,}120\ \mu g/L}$$

b. Gossan Well Water Average

$$C_f\ (1.480 \times 10^5) = 8.5\ mg/L\ (1.1537 \times 10^4\ ft^3) + 2.921 \times 10^5$$

$$C_f = \frac{0.9806 \times 10^5 + 2.421 \times 10^5}{1.480 \times 10^5}$$

$$\boxed{C_f = 2.64\ mg/L = 2{,}640\ \mu g/L}$$

c. Statistical Analysis Average Copper Concentration

$$C_f\ (1.480 \times 10^5) = 5.7\ mg/L\ (1.1537 \times 10^4\ ft^3) + 2.921 \times 10^5$$

$$C_f = \frac{0.6576 \times 10^5 + 2.921 \times 10^5}{1.480 \times 10^5}$$

$$\boxed{C_f = 2.42\ mg/L = 2{,}420\ \mu g/L}$$

III. Zinc–Estimated Concentrations
C_1 and C_2, Table 6-2, C_3, Table 6-3; Attachment B

a. **Leaching Studies Average**

$$C_f V_f = 12.05\ mg/L\ (1.1537 \times 10^4\ ft^3) + 4.66\ mg/L\ (1.4525 \times 10^4\ ft^3)$$
$$+ 0.067\ mg/L\ (1.2194 \times 10^5\ ft^3)$$

$C_2 V_2 + C_3 V_3 = 0.7586 \times 10^5$ (Does not change for IIIb and IIIc.)

$$C_f = \frac{1.3902 \times 10^5 + 0.7586 \times 10^5}{1.480 \times 10^5}$$

$$\boxed{C_f = 1.45\ mg/L = 1{,}450\ \mu g/L}$$

b. **Gossan Well Water Average**

$$C_f (1.480 \times 10^5\ ft^3) = 4.33\ mg/L\ (1.1537 \times 10^4\ ft^3) + 0.7586 \times 10^5$$

$$C_f = \frac{0.4996 \times 10^5 + 0.7586 \times 10^5}{1.480 \times 10^5}$$

$$\boxed{C_f = 0.85\ mg/L = 850\ \mu g/L}$$

c. **Statistical Analysis Average**

$$C_f (1.480 \times 10^5\ ft^3) = 8.5\ mg/L\ (1.1537 \times 10^4\ ft^3) + 0.7586 \times 10^5$$

$$C_f = \frac{0.9806 \times 10^5 + 0.7586 \times 10^5}{1.480 \times 10^5}$$

$$\boxed{C_f = 1.18\ mg/L = 1{,}180\ \mu g/L}$$

Table 6-2 *Summary of Copper and Zinc Concentrations used in* Calculations of Baseflow Metal Concentrations in Boulder and Slickrock Creeks

	Mean Copper (mg/L)	Mean Zinc (mg/L)
Gossan Well Waters and BG Seep[1]	8.5	4.33
One Week Gossan Leaching Experiments	27.5	12.05
PCA/SDA Analysis	5.7	8.5
Transition Zone Bedrock Batch Leach Experiment[2]	19.9	4.66

[1] Gossan Well Waters include average copper and zinc concentrations of Well Waters (Table 3-2) and BGSeep (*Section 3.6*).
[2] Bedrock Batch Leach Experiments include average of copper and zinc concentrations in Table 4-6 and the Mineralized Bedrock Sample in Table 4-9.

Table 6-3 Copper and Zinc Concentrations in the 2:1 Water:Soil Extractions of Non-waste Landslide Material (Model of Surface Runoff)

Sample ID	Copper (mg/L)	Zinc (mg/L)
Transect - Sample 1	0.003	0.042
Transect - Sample 2	0.020	0.105
Transect - Sample 3	0.041	0.039
Transect - Sample 4	0.058	0.114
Transect - Sample 5	0.025	0.083
Transect - Sample 6	0.004	0.017
Average	0.025	0.067

Note: All samples were collected from a transect between WR12 and WR18 (Figure 3-1).

Table 6-4 Calculated Average Stream Copper Concentrations for Maximum Winter High-Flow and Summer Low-Flow Conditions (Concentrations are in mg/L)[1]

Component	Leaching Studies[2]		Gossan Wells[3]		Statistical Analysis[4]		Published Literature Survey[5]	Published Russian Literature[6]
Maximum Winter High-Flow Conditions								
	Slickrock Creek	Boulder Creek	Slickrock Creek	Boulder Creek	Slickrock Creek	Boulder Creek		
Copper	1.06	0.34	0.56	0.26	0.49	0.25	<0.001 - 68	0.002 - 2.5
Zinc	0.45	0.16	0.25	0.13	0.36	0.15	<0.001 - 16	0.006 - 5.0
Summer Low-Flow Conditions								
	Both Creeks		Both Creeks		Both Creeks			
Copper	5.0		1.54		1.04		<0.001 - 68	0.002 - 2.5
Zinc	2.2		0.79		1.54		<0.001 - 16	0.006 - 5.0

[1] Value represents model calculations assuming dilution with mean copper and zinc concentrations in runoff from 2:1 water:soil equilibrations, and mean copper and zinc concentrations in mineralized bedrock below disseminated gossan outcrops shown in Table 6-3.
[2] Results of model calculation using mean value for one week leaching results copper (27.5 mg/L) and zinc (12.05 mg/L) from Table 4-2.
[3] Results of model calculation using mean value of copper (8.5 mg/L) and zinc (4.33 mg/L) (Table 3-2 and Section 3.6).
[4] Results of model calculation using the mean value of copper (5.7 mg/L) and zinc (8.5 mg/L) averaged from PCA/SDA anlyses Groups A, B, and C, excluding waters from the Hornet area and UND-01 (Table 5-2).
[5] See Appendix A.
[6] See Table 2-1

Results of Laboratory Testing
Surface Water and Ground Water Samples
Catfish Pond Area, Iron Mountain Mine

Sample ID	Sample Date	Source	SCDD Inflow (cfs)	pH	Dissolved Copper (ug/l)	Dissolved Zinc (ug/l)
SRPD	12-Dec-95	Surface Water	479	6.01	6.3	25.6
SRPD	10-Jan-96	Surface Water	11	6.72	5.1	33.4
SRPD	14-Feb-96	Surface Water	10	6.56	8.8	28.5
SRPD	22-Feb-96	Surface Water	130	5.82	9.4	20.7
SRPD	26-Nov-96	Surface Water	4	5.71	15.9	44.7
SRPD	04-Dec-96	Surface Water	15	5.38	26.3	63.8
SRPD	11-Dec-96	Surface Water	193	6.16	5.1	21.1
SRPD	30-Dec-96	Surface Water	737	5.99	3.7	17.3
SRPD	08-Jan-97	Surface Water	84	6.27	5.3	33.8

*Includes Upper Spring Creek flows after 12/31/96